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ARTICLE I.

On the maintaining Power in Clocks and Watches.

[Concluded from Page 429, Vol. I.]

IF we suppose the pendulum of a clock to preserve its length invariable * during all the changes of temperature to which it is exposed, its vibrations will measure equal portions of time so long as the arc of vibration continues the same. The resistance of the air and of friction are prevented, by the maintaining power, from destroying the vibration. This power may be applied in different parts of the arc; and may, according to circumstances, render the time of vibration either shorter or longer, or it may simply maintain it without altering the time. Whether it alter the whole time or not will be of no consequence to the performance of the regulated machine, provided the effect of the maintaining power is itself subject to no variation. For the thing required is, that all the vibrations, when once brought to an accurate adjustment, should continue invariable. It is therefore essential to a good time-piece, either, 1. that the maintaining power itself shall not vary; or, 2. that it should be applied to the pendulum or balance in such a manner, as that in all variations of the power itself the time of vibration may continue the same; or, 3. that it shall act during a very small part only of the time of vibration, in order that the effect of its variations may be less.

* Philosophical Journal, I. page 58.

When the train of wheels in a clock is driven by a weight, the more immediate cause of variation consists in the periodical irregularities of the wheels, the pinions, and the pivots, which transmit the force diminished by friction and oblique actions, which are by no means uniform: the remoter cause of variation consists in the oil becoming less fluid the longer it is exposed to the air. But when a train is driven by a main spring, the causes of irregularity are greatly increased by the diminution of force in the spring as it runs down, and its friction in the box; neither of which are so regular as to admit of a good correction from the spiral of the fusee round which the chain, that acts upon the movement, is drawn. Perfect equality of the maintaining power is not therefore to be expected. The only good expedient, independent of the escapement, appears to be that of causing the tr in to go by a weight or spring, serving only to wind up the last wheel once during every revolution, this wheel being urged by an appropriate weight or spring. By such an expedient the clock in effect becomes a time-piece with one wheel only, in which the irregularities are minute, and their recurrence too frequent to produce any considerable effect on the vibrating part.

When the irregularity of the first mover is proposed to be remedied by its mode of application, it is clear that it must give an increase of velocity to such vibrations as are performed through longer arcs, in order that the times may continue the same. Attempts have been made to accomplish this object, by giving a proper figure to the face of the pallets of the escapement; but it does not appear that such attempts have been successful.

The third method of equalizing the effects of the maintaining power with regard to time is founded on the consideration, that, if this impulse could be given in an instant, the whole of the vibration would be free, and resemble that of a disengaged pendulum or balance; and if the forces, by which the vibrating body returns to its point of quiescence, were as the spaces to be moved through, all the vibrations would be performed in equal times, whether long or short, or whether the maintaining power were greater or less. This disposition is peculiarly adapted to the balance. For it is possible to form the pendulum spring and adapt the maintaining power to so small a part of the vibration, that the times shall not perceptibly vary, even when the power itself is greatly altered.

Under the latter points of view the escapement becomes an object of great importance, since on this the manner of application of the maintaining power must depend. It scarcely seems necessary to subdivide or arrange the principles on which the most eminent artists have endeavoured to give perfection to their escapements. The principles will perhaps best shew themselves in the form of remarks upon the several constructions.

One of the most ancient escapements is that which is at present applied in common pocket watches. It is represented Fig. 1. Pl. III. and is best suited to the long vibrations of the balance, which was invented earlier than the pendulum *. A B denotes the rim of a con-

* Doctor Derham on Clockwork, p. 86. fourth edition, affirms, that vibrations are no where mentioned or alluded to in the clocks described by the ancients: yet we learn from Vitruvius that they possessed time-pieces with wheel-work. Falconet, *Academie des Inscriptions*, vol. xx. thinks that all the mechanical time-pieces made before the 16th century were clepsydræ with wheel-work for reckoning the smaller portions of descent.

a contrate wheel called the crown wheel, having its teeth pointed and sloped on one side only, so that the points advance before any other part of the teeth during the motion. C D are two pallets, or flaps, proceeding downwards from the verge E F. The pallets are nearly at right angles to each other; and when the balance F G fixed to the verge is at rest, the pallets remain inclined to the plane of the wheel in an angle of about 45 degrees; but when it is made to vibrate, one of the pallets is brought nearer to the perpendicular position, while the other becomes more nearly parallel. The wheel must be supposed to have one of its teeth resting against a pallet by virtue of the maintaining power. This tooth will slip off or escape as the pallet rises towards the horizontal position, at which instant a tooth on the opposite side of the wheel will strike against the other pallet which is down. The returning vibration, by raising this last pallet, will suffer that tooth to escape, and another tooth will apply itself to the first-mentioned pallet. By this alternation the crown wheel will advance the quantity of half a tooth each vibration, and the balance or pendulum will be prevented from coming to rest, because the impulse of the teeth against the pallets will be equal to the resistances from friction and the re-action of the air.

On this escapement it may be remarked, that the pendulum or balance is constantly connected with, and influenced by, the maintaining power, except during the exceedingly small time of the drop of the wheel from one pallet to the other; on which account the measure of time will greatly vary, when the force of vibration is merely equal, or not much greater than the maintaining impulse. This is shewn in a striking manner by urging the movement of a common watch by means of the key. If the key be pressed in the usual direction of winding up, the beats of the vibration will become very slow, or even stop; and if the pressure be made in the opposite direction, the vibrations will become very loud and quick.

descent. Professor Venturi, in his *Essai sur les Ouvrages Physico-Mathématiques de Léonard de Vinci*, page 28, has a curious note on this subject, from which I here make some extracts. The common escapement described in the text was well known to de Vinci, who describes an instrument acting by an escapement of this kind, similar, as he says, to the verge of the balance in watches, which he does not seem to mention as a new thing. He died about 1513. The isochronism of the pendulum was known to Galileo in 1600, who before his death, namely about 1633, proposed to apply it to clocks. The actual application by Huyghens was made before 1658, when he published his *Horologium oscillatorium*. He applied it by means of the common escapement already in use with the balance, and still retained in our table clocks. Sanctorius had made the same application near forty years before that time, as appears by his *Commentarii in Avicennam, (quest.* 56) printed in 1625, in which several instruments are described as having been publicly exhibited and explained to his auditors at his lectures in Padua for thirteen years previous to that time.

There is a manuscript (No. 7295) in the National Library of France, written about the middle of the 15th century by H. Arnault, Physician to the Dukes of Burgundy, who died in 1465. This author describes a planisphere which Jean de Fondeur *(Fusoris)* his master had constructed for the Duke, and which Arnault himself had afterwards repaired. Whence it appears that the instrument was constructed about the commencement of the 15th century. At folio 59 a design is seen of the watch which gives motion to the planisphere. It is nearly the modern watch. The balance is called *circulus affixus virge paletorum, qui cum ea de vi movetur.* He calls the crown wheel, which forms the common escapement on the pallets of the verge of the balance, by the name of *folietus*. At folio 60 the striking part is described, where we have the terms *voletus*, the *brochie levantes malleum*; *crux media inter movimentum et sonneriam*; *cavale* and *chivola* for *cheville*. M. Venturi thinks that the watches of Wallingfort and Dondi, in the 14th century, were constructed on the principle of the balance. Robert Hooke added the spring to the balance in the year 1658.

This escapement not being adapted to such vibrations as are performed through arcs of a few degrees only, another construction has been made which has been in constant use for about a century in clocks, with a long pendulum beating seconds. Fig. 2. A B represents a vertical wheel called the swing wheel, having thirty teeth. C D represents a pair of pallets connected together, and moveable in conjunction with the pendulum on the centre or axis F. One tooth of the wheel in the present position rests on the inclined surface of the inner part of the pallet C, upon which its disposition to slide tends to throw the point of the pallet farther from the centre of the wheel, and consequently assists the vibration in that direction. While the pallet C moves outwards and the wheel advances, the point of the pallet D of course approaches towards the centre in the opening between the two nearest teeth; and when the acting tooth of the wheel slips off, or escapes from the pallet C, another tooth on the opposite side immediately falls on the exterior inclined face of D, and by a similar operation tends to push that pallet from the centre. The returning vibration is thus assisted by the wheel, while the pallet C moves towards the centre, and receives the succeeding tooth of the wheel after the escape from the point of D. In this manner the alternation may be conceived to go on without limit.

The same observation which was made upon the escapement fig. 1. is applicable also to this; namely, that the vibrating part is constantly under the influence of the maintaining power, except during the interval of the drop, or actual escape of the wheel from one pallet to the other. The indirect action of an inclined plane, with the influence of oil which it necessarily requires, may also be mentioned to shew that this escapement is not equal to what might have been produced by a skilful variation of the other. One principal recommendation of this escapement seems to have been the facility with which it affords an index for seconds in the face of the clock. Though the pendulum, according to this construction, is constantly connected with the maintaining power in a clock, yet the variations of that power have not the same mischievous effect as in a watch, because the momentum of the pendulum, compared with the impulse of the maintaining power, is prodigiously greater in the former of these instruments. A very considerable change in the maintaining power of a clock with a long pendulum, will not cause a greater variation than a few seconds in the daily rate.

The celebrated George Graham improved this escapement very much by taking off part of the slope farthest from the points of the pallets; instead of which part he formed a circular or cylindrical face, having its axis in the centre of motion. Pallets of this kind are seen on the opposite side of the wheel at E and G, having H for their centre or axis. A tooth of the wheel is seen resting upon the circular inner surface of the pallet G, which is not therefore affected by the wheel, excepting so far as its motion arising from any other cause may be affected by the friction of the tooth. If the vibration of the pendulum be supposed to carry G outwards, the slope surface will be brought to the point of the tooth, which will slide along it and urge the pallet outwards during this sliding action. When the tooth has fallen from the point of this pallet, an opposite tooth will be received on the circular surface of E, and will not affect the vibration, excepting when the slope surface of E is carried out so as to suffer the tooth to slide along it. In the two former escapements there is always a certain portion of vibration takes place after the drop which drives the pallets back, and causes the index also to recede through a small arc. This has been distinguished

diftinguifhed by the name of a recoil. Other confiderable objections, befides that of the continued action of the maintaining power, have been made againft efcapements with a recoil; but it would lead us too far into the minute departments of this fubject to difcufs them. The efcapement of Graham, and all fuch as have no recoil, have been called dead beat efcapements, becaufe the index for feconds falls directly through its arc, and remains motionlefs on the line of divifion till the next vibration. It may be obferved, that the maintaining power in Graham's efcapement may be applied during a fmall portion only of the vibration; and that an increafe of the maintaining power tends to enlarge the arc of vibration, but fcarcely interferes with its velocity.

The effect of the efcapement which has been called horizontal *, becaufe the laft wheel in watches of this conftruction has its plane parallel to the reft of the fyftem, is fimilar to that of the dead beat efcapement of Graham. In fig. 3, the horizontal wheel is feen with twelve teeth, upon each of which is fixed a fmall wedge fupported above the plane of the wheel, as may be feen at the letters A and B. On the verge of the balance there is fixed part of a hollow cylinder of fteel or other hard material, the imaginary axis of which paffes through the pivots of the verge. C reprefents this cylindrical piece, into which the wedge D may be fuppofed to have fallen. While the vibration caufes the cylindrical piece to revolve in the direction which carries its anterior edge towards the axis of the wheel, the point of the wedge will merely rub the internal furface, and no otherwife affect the vibration of the balance than by retarding its motion. But when the return of the vibration clears the cylinder of the point of the wedge D, the wheel will advance, and the flope furface of the wedge acting againft the edge of the cylinder will affift the vibration of the balance. When the edge of the cylinder arrives at the outer point of the wedge D, its pofterior edge muft arrive at the pofition denoted by the dotted lines of continuation; immediately after which the wedge or tooth E will arrive at the pofition e, and reft on the outer furface of the cylinder, where it will produce no other effect than that of retardation from friction, as was remarked with regard to the wedge D, until the courfe of the vibration fhall bring the pofterior edge of the cylinder clear of the point of the wedge. In this laft fituation, the wedge will act on the edge of the cylinder, and affift the vibration, as in the former cafe, until that edge fhall arrive at the outer or pofterior point of the wedge; immediately after which the leading point will fall on the inner furface of the cylinder in the firft pofition, as was fhewn in the wedge D.

* In the feventh volume of *Machines et Inventions approuvées par l'Academie Royale des Sciences*, I find, p.137, that the Sieur *Baufré*, a French clock-maker, fettled in London, contrived the horizontal fcapement in 1704. He applied an hollow portion of a cylinder to the verge of the balance, the edges of which were thick enough to afford the inclined furfaces of Graham's pallets, and thefe were acted upon by two common wheels perfectly fimilar and fixed on the fame axis, fo that the teeth of one correfponded with the hollows of the other. In the fame work, p. 141, the Regle artificielle du temps of Sully, p. 248—251, is quoted to fhew that Sir Ifaac Newton poffeffed one of thefe watches, marked with the name of Baufré. Peter le Roy improved this fcapement by fubftituting a portion of a cone inftead of the cylinder (Machines et Inventions, 1742), with a double wheel, the axis of which was at right angles to the verge. And M. Gourdain, in the fame year (p. 141 of the work laft quoted), made another conftruction, in which a flat circular piece of metal, out of which a portion of about 90° was cut, was fubftituted in the place of the cylinder, and received the action of a wheel with wedge-teeth, acting alternately in oppofite directions in the notch, and refting on the flat furface of the metal during the time of repofe. The fcapement defcribed in the text appears to have been a combination of the inventions of Baufré and Gourdain.

Horizontal watches were greatly eſteemed during the laſt thirty years, until lately, when they gave place to thoſe conſtructions which are known by the name of detached or free eſcapements. In the common eſcapement, fig. 1, an increaſe of the maintaining power increaſes the recoil, and accelerates the vibrations; but with the horizontal eſcapement there is no recoil; and an increaſe of the maintaining power, though it may enlarge the arc of vibration, will not neceſſarily diminiſh or alter the time. It is accordingly found, that the experiment of altering the maintaining power by the application of the key, does not alter the rate in the ſame perceptible manner as in common watches. Exceedingly perfect time-pieces on the horizontal principle, with a compenſation for temperature applied to the ſpring, were made about fifteen years ago by Emery, of Charing-croſs, and other artiſts; but I am informed that their performance became ſenſibly leſs accurate after a few years wear. Whether the difficulty of execution, or the badneſs of workmanſhip in low-priced watches of this kind, or whether the ſubſequent great improvements in this uſeful engine, have cauſed the horizontal principle to be laid aſide, I know not; but I believe few if any watches of this conſtruction are at preſent made.

The dead beat eſcapement of Graham, and the horizontal eſcapement, both appear to be improvements of the common anchor eſcapement, fig. 1. which by theſe expedients is deprived of its recoil, but ſtill retains the wedge action, which has much friction, and neceſſarily requires oil. The quantity of direct puſh in the eſcapement fig. 1, which requires no oil on the face of the pallets, appears to be the cauſe why it acts ſo freely, and is ſo little liable to injury or diſorder. I wiſh it were leſs difficult to aſcertain the inventors and improvers of uſeful contrivances. But in proportion to the utility and univerſal adoption of any inſtrument, it always becomes more eaſy to mention it by a ſingle term. Definitions, deſcriptions, and inventors' names naturally become diſcarded; and from this cauſe it ſeems as if a moderate or a ſpeculative invention might carry the name of its inventor to remote ages, while the great benefactors of ſociety are forgotten. I do not know who firſt undertook to improve eſcapements by pallets reſembling thoſe of fig. 1. in the direct action they receive; but the earlieſt contrivance of this kind I have met with is that of M. Le Roy fils aîné, of which the account bears date Sept. 6, 1748. As it is in effect the ſame eſcapement as is now in the higheſt eſteem in the time-pieces of our beſt artiſts, I ſhall here deſcribe the latter, and mention the particulars of that of M. Le Roy in a note.

Fig. 3. Pl. III. repreſents the free eſcapement of our beſt portable time-pieces. Fig. 4. exhibits the eſcapement on a larger ſcale. On the verge of the balance is fixed a circular piece of ſapphire, or hard ſteel, EL, out of which a ſectoral piece is cut. HG is a ſtraight ſpring fixed near its extremity H, and having at the other extremity a pin G, againſt which one of the teeth of the wheel D reſts when the train is at reſt. This ſpring has a ſlight tendency towards the centre of the wheel, but is prevented by the ſtop K from throwing the pin farther inwards than juſt to receive the point of the tooth. I is a very ſlender ſpring fixed at the end I, and preſſing very ſlightly againſt the pin G, in a direction tending to throw it from the wheel D, but which on account of the greater power of HG it cannot effect. It may be obſerved that the ſpring I proceeds a little beyond the pin G.—F is a lever proceeding from the verge of the balance directly oppoſite the end of the ſpring I, and long enough to ſtrike it in its vibration. The action is as follows:—From

the preſſure of the main ſpring the wheel (fig. 4) is urged from D towards F, but is prevented from moving by the pin G. Let the balance be made to vibrate, and the lever F will move through the arc Ff, ſtrike the inner extremity of the ſpring I, and diſplace the pin G. At this inſtant the face E, which may be called the pallet, will have arrived at the poſition e, againſt which the tooth of the wheel will fall, and communicate its impulſe through about 15° or 16° of the vibration. But F quits the ſpring I ſooner than the wheel quits the pallet E, and conſequently the pin G will have returned to its firſt ſtation before the wheel can have advanced a whole tooth, and the ſpring or detent HG will receive the wheel as before, immediately after its eſcape from the pallet. The returning vibration of the balance will be made with the piece EL perfectly at liberty between two teeth of the wheel, as in the ſketch, and the back ſtroke of the lever F againſt the tender ſpring I, will have no effect whatever on the pin G; this ſpring being like the back ſpring of the jacks of the harpſichord, active in one direction only. The third vibration of the balance will unlock the detent as before; the impulſe will again be given, and the whole proceſs will be repeated; and in this manner, the balance, though it may vibrate through the greateſt part of the entire circle, will be entirely free of the works, except during the very ſmall time of the drop of the wheel*.

It is hardly neceſſary to make any remark on this eſcapement. It requires little or no oil; and when all the parts, particularly the pendulum ſpring, are duly adjuſted, it is found that a very great variation in the firſt mover will remarkably alter the arc of vibration without affecting the rate. The piece EL might have conſiſted of a ſingle pallet or arm, inſtead of a portion of a circle or cylinder; but ſuch a piece would have been rather leſs convenient to make in ſapphire, or ruby, as in the beſt time-pieces, and would alſo have been leſs uſeful. For if by any accident or ſhock the pin G ſhould be diſplaced for an inſtant, the wheel D will not run down, becauſe it will be caught upon the circular ſurface of EL.

* The echappement à détente of Le Roy (Recueil des Machines, &c. VII. 385) was different from the above deſcribed in ſeveral particulars not eſſential to the general principle. 1. The wheel was contrate, and in the drawing has 44 thin teeth. 2. The face E was afforded by an actual pallet concave towards the tooth. 3. The detent was forked, and moved on pivots at the angular point. One leg preſented a ſtop to one of the teeth of the wheel, while the other leg reſted againſt the periphery of a ſemi-cylinder upon the verge of the balance. The detent was kept to this poſition by a tender back ſpring. 4. In the actual performance the vibration of the balance carried the ſemi-cylinder clear of the leg of the detent, which conſequently would have quitted the wheel, if the back ſpring had been ſtrong enough. Immediately after the arrival at this poſition, the pallet ſtruck a tooth of the wheel, made it recoil, and delivered the detent, which flew inwards againſt the radius of the ſemi-cylinder. The wheel being thus ſet at liberty, was driven back through an angle of near 20°, as I eſtimate from the drawing, and then in its return followed the balance through about 60° or 70°, during which period the ſemi-cylinder recovered the poſition requiſite to throw the detent in the way of the ſucceeding tooth, and retain the wheel, while the balance continued its vibration, diſengaged from every action but that of the rub of the ſemi-cylinder againſt the tail of the detent. The judicious mechanic will perceive that the diſpoſition of the parts in the eſcapement fig. 4. are much for the better. For (a) the flexures of ſprings afford a leſs variable deduction from the moving force, than the frictions of ſurfaces in the pivots of Le Roy's detent, and his ſemi-cylinder. (b) The force loſt in the recoil is greater and more variable than that employed againſt the ſpring I in fig. 4. (c) The balance is perfectly diſengaged for a much larger portion of both vibrations in the modern, than in the original eſcapement, and (d) the ſmall number of teeth in the wheel D affords an advantage in regulating the figure and contacts of the parts.

It is indeed very easy to observe, that the piece EL would operate without the detent, though with much friction during the time of repose. The tooth of the wheel would in that case rest upon its circular face.

This escapement is better calculated for a long than a short vibration. I have seen it adapted to an half seconds pendulum clock, in the form delineated in fig. 6, Pl. III. It kept up a vibration of 8° with a very heavy pendulum, and no great maintaining weight, but I was not informed of the quantities of these weights. The part ABDC is fixed to the pendulum rod. BC is a lever moveable on the joint B, but not capable of falling below its horizontal position. It terminates in a claw at C. At D is a pallet of agate or hard stone, having a flat polished face. F G H I is a detent moveable on the centre H, but kept in its position against the pin or stop K, by means of the counterpoise G. As it is now represented, a tooth I of the wheel bears against the end of the lower arm or branch. Suppose the pendulum to be made to vibrate, and it will pass clear of the teeth I L; but when the claw C strikes against the upper end F of the detent, the slope surface of those extremities will cause the lever B C to rise, and the claw in its return will draw F towards the wheel, and consequently disengage I. The tooth E will therefore fall on the pallet D, and impell the pendulum in its vibration; but before it quits the pallet the claw C will be drawn away from F, and the counterweight G will restore the original position of the wheel, which will receive and hold the tooth M during the whole of the vibration made in the direction B C. The next vibration in the opposite direction will displace the detent as before, and by these alternations the motions will continue so long as the maintaining power continues to act.

In the two last escapements we have seen the variable effects of the maintaining power almost entirely removed, as far as can be practically discerned. Fig. 7.* exhibits the escapement of Mudge, in which the balance is perfectly detached from the train of wheels, except during the extremely short interval of striking out the parts which serve the purpose of detents. O N E B Q is the circumference of the balance, vibrating by the action of a spiral spring as usual on its axis C A D H passing through the centre C: the axis is bended into a crank, A X Y D, to make room for the other work. L M, Z W, are two rods fixed to the crank at the points L and Z, parallel to X Y. c d e f r s are fixed parts of the machine. T R is an axis concentric with that of the balance, and carrying an arm G o nearly at right angles to it, and a small auxiliary spring u, which is wound up whenever the arm G o is moved in the direction o h. p is a curved pallet fixed to the axis T R, which receives the tooth of the balance wheel near the axis. The tooth, proceeding along the curved surface, by the force of the main spring turns the axis and its arm G o, and winds up the spring u. A small projection at the extremity of the curved surface of the pallet p prevents the farther progress of the tooth, when the arm o G has been turned through an arc o h, of about 27°; and, consequently, the spring u has been wound up through the same angle or arc, o G h = 27°.——F S is another axis exactly similar to TR. It carries its arm I o, and spring v, and the tooth of the balance wheel l m winds up the

* From Atwood's Investigations for determining the Times of Vibration of Watch Balances. Philos. Trans. 1794.

spring

ſpring v, by acting on the pallet q, and is detained by a projection, after having carried it through an angle of 27°, exactly as in the former caſe. The arcs paſſed through by the arms G o and I o, and marked in the figure, are alſo denoted by the ſame letters on the rim of the balance.

The effect of this eſcapement may be thus explained: Let the balance be in the quieſcent ſtate, the main ſpring being unwound, and the branch or crank in the poſition repreſented in the figure. If the quieſcent points of the auxiliary ſprings coincide with that of the balance ſpring, the arm G o will juſt touch the rod L M, and in like manner the arm I o will juſt touch the rod W Z; the two arms G o and I o in this poſition are parallel to the line C O. This poſition of the balance and auxiliary ſprings remains as long as the main ſpring of the machine continues unwound; but whenever the action of the main ſpring ſets the balance wheel in motion, a tooth thereof meeting with one or other of the pallets p or q, will wind up one of the auxiliary ſprings; ſuppoſe it ſhould be the ſpring u. The arm G o being carried into the poſition G h, by the force of the balance wheel acting on the pallet p, remains in that poſition as long as the tooth of the balance wheel continues locked by the projection at the extremity of the pallet p; and the balance itſelf not being at all affected by the motion of the arm G o, nor by the winding up of the ſpring u, remains in its quieſcent poſition: conſequently no vibration can take place, except by the aſſiſtance of ſome external force to ſet the balance in motion. Suppoſe an impulſe to be given ſufficient to carry it through the ſemi-arc O B, which is about 135° in Mr. Mudge's conſtruction.

The balance, during this motion, carries with it the crank A X Y D, and the affixed rods L M, Z W. When the balance has deſcribed an angle of about 27° = the angle o C h, or o G h, the rod L M meets with the arm G H, and by turning the axis T R, and the pallet p in the direction of the arc o h, releaſes the tooth of the balance wheel from the projection at the extremity of the pallet p: the balance wheel immediately revolves, and the lower tooth meeting with the pallet q, winds up the auxiliary ſpring v, and carries the arm I o with a circular motion through the angle o I k, about 27°, in which poſition the arm I o remains as long as the tooth of the balance wheel is locked by the pallet q. While the ſpring v is winding up through the arc o k, the balance deſcribes the remaining part of the ſemi-arc h B, and during this motion the rod L M carries round the arm G h, cauſing it to deſcribe an angle h C B, or h G B, which is meaſured by the arc h B = 108°. When the balance has arrived at the extremity of the ſemi-arc O B = 135°, the auxiliary ſpring u will have been wound up through the ſame angle of 135°, that is to ſay, 27°, by the force of the main ſpring acting on the pallet p, and 108° by the balance itſelf, carrying along with it the arm G o, or G h, while it deſcribes the arc h B. The balance therefore returns through the arc B O, by the joint action of the balance ſpring and the auxiliary ſpring u; the acceleration of both ſprings ceaſing the inſtant the balance arrives at the quieſcent point o. When the balance has proceeded in its vibration about 27° beyond the point O, to the poſition C k, the rod Z W meets with the arm I k, and by carrying it forward releaſes the tooth of the balance wheel from the pallet q. The balance wheel accordingly revolves, and the upper tooth meeting with the pallet p winds up the auxiliary ſpring u, as before. The balance with the crank proceeding to deſcribe the

the remaining semi-arc k E, winds up the spring v through the further angle k C E = 108°, and returns through the semi-arc E o, by the joint action of the balance spring and the auxiliary spring v, both of which cease to accelerate the balance the instant it has arrived at O.

It may be remarked, in this curious escapement, that the motion of the balance in its semi-vibration from the point of quiescence is opposed through an arc of no more than 108, but is accelerated in its return through the whole arc of 135°, and that the difference is what maintains the vibrations; and moreover, that the force from the wheel being exerted to wind up each auxiliary spring during the time it is totally disengaged from the balance, this last organ cannot be affected by its irregularities, except so far as they may render it more difficult to disengage the rim of the pallet from the tooth. The balance describes an arc of about 8° during this disengagement.

From a passage in a pamphlet of Mr. Mudge, printed in 1763, which I have seen, and is quoted by Count Bruhl *, it is clearly shewn that that artist had the notion of the principle of this escapement in his mind at least thirty-five years ago. From the same author's description it appears that Mudge had organized his notions in the present form before August 1771, and completed his first time-keeper two years afterwards, viz. in 1773. The performance of such time-keepers as have been made on this construction has proved excellent, but not superior, as I am informed, to such as have been made with the escapement No. 4. There are, however, many circumstances in the execution of the workmanship of engines of this delicate nature, which must affect their performance whatever may be their principle. The theory of Mudge's escapement appears to be more perfect than that of the other. But whether its six pivots in the time-measurer, which require oil and adjustments for position when intended for the pocket, and the care required in settling the points of quiescence in the three distinct springs, may render it less easy to be carried into practical effect, will be in a great measure an object of opinion, into which I cannot now enter.

If Mr. Mudge was the first who imagined an escapement absolutely detached, I think it is to Mr. Alexander Cumming that we are indebted for the first execution of a like contrivance of his own. This well-known artist, in the year 1763, made a clock for the king, in which there was no friction during the repose of the movement, and the maintaining power was applied to the inclined faces of a pair of pallets†; and some time previous to 1766, he improved the same so as to render it as perfectly detached as, in the nature of things, an escapement can be. As this has been so many years in possession of the public, and is, as I think, simplified in the sketch, fig. 8,—I shall only say that it consists of an anchor like that of Graham, but having a detent or claw at each end instead of pallets, and two separate pallets pressed (by a lever and weight to each) towards the centre of a wheel like AB, fig. 2; that these pallets are severally raised during the absence of the pendulum, which displaces the detent, by virtue of which, when the pendulum becomes joined with either, the maintaining force is constant and greater in the descent than in the ascent. It seems reasonable to infer, that Mr. Mudge must have paid great attention to the escape-

* On the investigation of astronomical circles; (page 3, of register) a pamphlet of 32 pages octavo, printed in London 1794.

† Cumming's Elements of Clock and Watch Work, p. 78.

ment of Cumming during his labours for organizing his own, which he did about five years afterwards.

Fig. 8. is the ſketch of an adaptation of Mudge's eſcapement to a clock. LM is part of the periphery of the wheel. GA, GB, are two arms ſeparately moveable on the ſame axis, and terminating in the pallets A, B. Theſe pallets have inclined faces, with a claw or detent at the lower part of each. GO, IO are tails proceeding from each pallet-piece reſpectively, and the dark ſpot at N repreſents a pin proceeding from the pendulum rod, and capable of moving either of the tails according to the courſe of the vibration. The dotted circles u and v repreſent weights which are ſtuck upon two pins, and may be changed for others, greater or ſmaller, until the moſt ſuitable quantity is found. Suppoſe the wheel to be urged from L towards M, and the pendulum made to vibrate by external impulſe. The pin N proceeding towards L will ſtrike the tail G O, raiſe the pallet A, and ſet the wheel at liberty; which ſliding along the inner ſurface of the pallet B, will raiſe it, and ſtop againſt the claw at its lower end. I O will conſequently be carried into the poſition IP; and the pallet A in its return will be oppoſite a vacancy, which will permit the tail GO to follow the pin N as far as the perpendicular ſituation. The pendulum will therefore be aſſiſted by the weight u through a longer arc in its deſcent, than it was impeded by it in its aſcent. In the oppoſite ſemi-vibration towards M, the pendulum will proceed unoppoſed by v, while it paſſes through the angle OIP, when it will raiſe B, and permit the wheel to elevate the pallet A. In the motion on this ſide of the perpendicular, it is alſo clear that the deſcent will be more aſſiſted than the aſcent was impeded. Whence it follows that the clock will continue to go: and no variation of the force of the wheel LM, which raiſes the pallets in the abſence of the pendulum, will affect the vibration, except ſo far as it may afford a variable reſiſtance at the detent or claw.

From obſerving that the detached eſcapements require a very ſtrong firſt mover*, and that pendulum clocks meaſure time with great accuracy by means of Graham's dead beat eſcapement, fig. 2, notwithſtanding the influence of oil and friction during the repoſe of the movement, I was induced to contrive an eſcapement which ſhould be as free as the crown wheel eſcapement, but have no recoil or action during the time of reſt, nor any detent, nor require oil on its pallets. I made a drawing at the beginning of the year 1784, which I ſhowed to various mechanics at that time. It has ſince been adapted to a clock in my poſſeſſion, and has been going very freely for a year paſt. Fig. 9 is a ſketch in which GH repreſents a ſteel wheel; D and E are pallets of agate, with flat poliſhed faces. The pallet D is fixed to the lever DC, which is confined to its preſent ſituation by the loaded branch or arm CB reſting on the ſtop k. The lever EC is alſo kept in its ſituation

* A pocket time-piece by Brockbank, making 5 vibrations, or $2\frac{1}{2}$ beats per ſecond, the radius of whoſe balance was 0.35 inch, and arc deſcribed by the external ſurface of the expanſion pieces 0.45 inch radius, was maintained by a force which, on trial at the axis of the fuſee, proved equal to $9\frac{1}{2}$ oz. troy, paſſing through 12 inches in 24 hours. Another, of the ſame dimenſions and conſtruction, was driven by $11\frac{1}{4}$ oz. with the ſame daily fall. And a large box time-keeper of Arnold, beating half-ſeconds, with a balance of two radii, each one inch long, was maintained by a like force of 113 ounces. This is nearly as much as is required to afford a ſemi-vibration of $3\frac{1}{2}°$ in a clock, with a ſeconds pendulum of 8lb. by the common eight-day train with Graham's eſcapement (fig. 2.), but three times as much as is required for a well made regulator. A common watch with a balance 0.8 inch diameter, was found to have a maintaining power of $5\frac{1}{4}$ oz. falling daily through 12 inches.

by the loaded arm CA refting upon I. A pin N proceeds from the pendulum rod to its fituation between the levers. The centre of motion of the pendulum is in the continuation of the axis of the pallets. Suppofe the vibration to be begun, the pin N in its progrefs will lift the pallet D towards L, while part of the weight B will be fupported by the tooth of the wheel which will follow, and at laft efcape, and fuffer the oppofite tooth F to fall on the pallet E. But in its return or defcent the pendulum will be acted on by the whole weight B, and confequently its vibration will be kept up. When the pin N raifes the pallet E, a fimilar effect will take place on the fide of the perpendicular towards M, and thus the procefs will go on as long as the wheel GH retains any force.

The ancient efcapement with the crown wheel, verge, and pallets, has continued in ufe for three centuries, becaufe of the advantage of an almoft direct pufh againft a retiring furface, which enables it to go without oil. In the efcapement laft defcribed, the impulfe being more direct than on thofe common pallets, it goes more freely without oil; and inftead of the re-action at the ends of the vibrations, the pendulum is perfectly difengaged during the whole time of repofe.

From this general view of the principal efcapements, together with that of the compenfations for temperature before explained*, the philofophical reader may form fome eftimate of the cautions requifite to form the valuable inftrument by which a meafure of time is afforded. I hope it fcarcely need be added, that I have endeavoured to do juftice in the hiftorical narration, and fhall be happy to rectify any miftakes, if better information fhould detect them.

II.

Copy of a Letter from Profeffor WILSON, *of Glafgow, on the Art of multiplying Copies of engraved Plates and Stamps in relief*†.

SIR, *Glafgow College, 23d March,* 1798.

I DOUBT not but you will have the goodnefs readily to excufe the liberty which I take upon the prefent occafion of addreffing you by a printed letter. I have been induced to do fo, the more conveniently to communicate to you fome account of what poffibly may be thought entitled to the appellation of a NEW ART, and which, for particular reafons, it has been thought adirfeable to make more or lefs generally known, even at this very early ftage of it.

Some years ago, upon the difcovery of the fingular property of the fluor acid in corroding glafs, when it was fo common to hand about bits of glafs-plate frofted over by this chemical agent, it happened to ftrike me that we were indulging too long in a barren admiration of mere novelty, and overlooking a matter of real importance to which it evidently pointed. The general effect of what then fo much amufed us, when the plates

* Philof. Journal, I. p. 56.

† I firft faw this letter at Sir Jofeph Banks's; but having fome doubt as to the propriety of requefting it of him for publication, I fent to Mr. Taffie, who favoured me with another copy for that exprefs purpofe. N.

were

were viewed by tranſmitted light, ſuggeſted the poſſibility of formally etching with delicacy and perfection upon glaſs. This thought no ſooner occurred than it challenged ſome attention in conſequence of perceiving that glaſs, from its extreme hardneſs and lubricity, would preſerve the execution beſtowed upon it vaſtly longer than copper-plate, were it poſſible to introduce its ſervices at the rolling preſs. But whilſt harbouring theſe ſurmiſes, the extreme fragility of glaſs-plate, contraſted with the violent preſſure it muſt endure between the rollers, had well nigh made me relinquiſh them altogether. It often happens, however, that things, which at the firſt glance ſeem very unattainable, yield to a little reflexion, when they are fairly ſet before the mind in the light of valuable deſiderata.

In the preſent caſe it ſoon became very evident, that the thinneſt and frailеſt piece of glaſs-plate, whether ſtraight or uneven, could, in regard to the ſtrongeſt preſſure, either general or topical, be rendered as robuſt and as rigid as iron or ſteel. The expedient which occurred to me for that purpoſe, conſiſted in nothing but joining the glaſs-plate to flat pieces of theſe metals, of conſiderable thickneſs, by an intervening lamina of proper cement, taking care that it affords a very complete contact.

Agreeable to this it is well known, that ſo far back as the year 1791, by fortifying glaſs-plates of a moderate ſize in this way, and aiding them further by a ſimple apparatus on the preſs board, I ſucceeded completely in making them paſs ſafely between the rollers, and in obtaining many impreſſions, ſuch as the fluor acid by the proceſs of etching could afford. Upon finding, however, that the beſt of theſe etchings were very paltry, and ſtill regarding the ſafe paſſage of the glaſs between the rollers as an intereſting experiment, I was inſenſibly led to conſider, whether by the lapidary's wheel, or by any other poſſible means whatever, we could ſo operate upon glaſs-plate as to render it a productive ſubject at the rolling preſs. This ſtep appeared of ſome conſequence, as being all that was now wanted for eſtabliſhing an improvement not deſtitute of importance. Not long after, certain views and methods occurred to me, which recently have been proſecuted experimentally, and which raiſe conſiderable expectations of our obtaining the maſtery over an art, whereby the tame ſcratchings of the fluor acid would be left far behind, and the execution and ſpirit of the graver itſelf transferred from copper-plate to glaſs-plate, in inſcriptions of all kinds, and in deſigns or embelliſhments of any ſort, eſpecially where hatching conſtitutes the manner; and all this with the further advantage, that any number of ſuch glaſs-plates may be obtained quite alike, as being derived from the ſame original pattern.

The means of effecting a matter of ſuch apparent difficulty, like moſt other advances in the Arts, or even in the Sciences, as ſoon as ever propounded, will, doubtleſs, be thought extremely ſimple and obvious. But whatever ſmall portion of merit may be allowed in the preſent inſtance, ſhould the means prove fully adequate to the end, it will partly conſiſt, as will be ſeen immediately, in my having given an entire new direction to another ingenious art which has been long cultivated, and by none with ſo much genius and ability as by the juſtly celebrated Mr. Taſſie of London.

In November laſt, certain circumſtances recalling my attention to the preſent object, I was led to explain, by letter to Mr. Taſſie, the method of printing at the rolling preſs with glaſs-plates, and to ſpecify to him, at ſome length, the ſteps by which I wiſhed him im-

mediately to proceed, in attempting for me the execution of caſts or copies in glaſs from certain copper-plates which I ſent him, and which I had got engraved here for the purpoſe. It afforded me much ſatisfaction to find that this eminent artiſt received my application with great candour, and that he purſued the object pointed out with promptneſs, about which I had applied to him in the line of his profeſſion. Though, indeed, at the beginning ſome difficulties ſtood in the way, yet by a repeated correſpondence, and tranſmiſſion of different eſſays from his furnace, anſwering to patterns ſent up at different times by the mail coach, Mr. Taſſie ſoon furniſhed me with ſeveral caſts in glaſs and enamel, from engraved copper-plates, which appear to juſtify my firſt conceptions, and to go ſome length, even thus early, to enſure the ſucceſs of the plan and method, which I had brought forward.

The other day I made ready for printing, three of theſe plates; two of them bearing inſcriptions, and the other a head in profile from Le Brun. I might have mentioned that the plates, when fully finiſhed, have an appearance of great elegance; thoſe eſpecially which are made of white glaſs, called enamel; and it is remarkable how eaſily they are cleaned from the ink, in the courſe of the workmen's operations, though they never are heated farther than by handling them. From the three plates above mentioned, I now take the liberty of ſending you proofs *, or impreſſions, incloſed. So far as I know, they are the firſt of the kind ever produced. As the very firſt offerings, therefore, of a new art, they may poſſibly appear to you in a light more or leſs intereſting, and as an earneſt of ſomething conſiderably more perfect ſoon to follow, when we are aſſiſted by engravings of ſome elegance, and executed with more addreſs in ſeveral reſpects, with a view to a deſtination ſo peculiar.

It will not eſcape you, that by means of a ſeries of glaſs-plates, inconſiderable in point of number, deriving the engraving from the ſame original pattern, to ſucceed one another at the preſs, juſt before ſigns of wearing might appear, a vaſt many impreſſions, all *perfectly ſimilar*, might be obtained, even for ages. This at once would be beſtowing a new character upon the rolling preſs, which hitherto has been much circumſcribed in this reſpect, by the periſhable nature of engraved copper-plates, and from their having no relation to any common archetype. Much could be ſaid of the advantages of thus commanding an ever enduring identity amongſt the impreſſions afforded by engraved plates, even of a ſmall ſize, eſpecially in the inſtance of circulating Bank Paper. I confeſs, indeed, it was the frequent alarming forgeries upon ſuch currency, eſpecially that of the Bank of England, which moved me in November laſt to bring to experiment the preſent ſcheme, which has been for ſeveral years in my mind. Should the glaſs-plates be carried to a ſufficient pitch of delicacy, I perceive, on ſeveral accounts, that they would afford a refuge of ſingular importance againſt all attempts of forgery; provided we were to found upon archetypes of copper-plate highly elaborated, and, beſides the mere inſcription, exhibiting by collateral embelliſhment the peculiar manner of ſome eminent maſter in the art of engraving.

* It would have been evidently uſeleſs to have copied theſe plates by way of exhibition to the reader. They are not diſtinguiſhable from copper-plate prints; unleſs, perhaps, by ſome minute circumſtances ariſing from the ſubſequent poliſhing of the glaſs. But this laſt obſervation muſt be uncertain, unleſs proofs from the original copper were alſo had for compariſon. N.

Before

Before concluding, I may juft mention, that fhould the methods followed by Mr. Taffie, of moulding with plaifter of Paris and Tripoli, not afford fufficient delicacy to the plates, I am already not without other refources likely to carry us farther in arrefting an art, which feems recommended by views of confiderable utility. I allude here partly to a method which occurred to me more recently, of having the original engraving done upon a flat and polifhed furface of fteel, which, by the fly prefs, may be communicated to a flat and polifhed piece of pure gold. This to ferve in the furnace as a *permanent mould* for giving the impreffion to the glafs. From fome experiments I have actually made in a fmall way, it fhould feem as if this procefs promifes well; particularly, by giving the fire furface ftill more delicacy, and which, confequently, would require a fmaller degree of finifhing, in the procefs for bringing it ultimately to a fufficient polifh; upon which circumftance alone, now depends the certainty of our being able virtually to engrave upon glafs-plate, with a very confiderable degree of perfection. Should it be neceffary in the end to refort to the gold, Mr. Taffie's confummate fkill and addrefs at the furnace, in the application of the glafs, would doubtlefs contribute greatly to the fuccefs.

One recommendation amongft others of this method would be, that, from the indeftructible nature of pure gold, if properly managed in applying the heat, all the plates would actually be derived from one and the fame mould; whereas, by the other method, the moulds themfelves, which are neceffary for every caft, are derivative, though indeed from the fame original pattern.

I have the honour to be, Sir,

Your moft obedient fervant,

PAT. WILSON.

P. S. I have purpofely referved, to follow in a poftfcript, a very fhort mention of another fubject bearing a clofe analogy to the foregoing.

You may perhaps know that of late years the art of cutting defigns upon box-wood has arrived at an uncommon degree of perfection, and that the celebrated Meffrs. Bewicks, efpecially, have carried their execution in this refpect to a pitch of elegance rivalling copper-plate, and which was believed to be utterly unattainable before their time.

Having often regretted that fuch rare fpecimens of art, as they have produced, were fo perifhable, from the frailnefs of the materials upon which fo much genius and labour were expended, I was induced alfo to fend to Mr. Taffie, amongft other models, fome defigns in box-wood, executed by Mr. Bewick, with directions to mould from them, in the view of obtaining cafts or copies in glafs. The returns which I received to all thofe patterns completely anfwered my expectations, as being at once as perfect as the originals.

From the fuccefs of this experiment, which alfo I have had long in contemplation, and from what has been eftablifhed in the way of making glafs fafely refift any preffure, it will readily occur that an improvement of confiderable magnitude has now been fhown evidently to depend upon a proper co-operation of the two arts of engraving upon box-wood, or upon brafs, and of moulding, with a view of obtaining fuch cuts or engravings in fo durable a fubftance as glafs.

P. W.

III. *Inftructions*

III.

Inſtructions concerning the Manufacture of Steel, and its Uſes. By VANDERMONDE, MONGE, and BERTHOLLET. *Publiſhed by Order of the Committee of Public Safety**.

Preliminary Obſervations.

IRON is a combuſtible body. It loſes its metallic properties by being burned. When iron filings are expoſed to ſtrong heat in a crucible, and frequently ſtirred to bring the parts ſucceſſively in contact with the air, the metallic aſpect diſappears. It aſſumes a brick-duſt colour, and is found to have increaſed in weight. Part of the air of the atmoſphere has combined with it, and produced this change. This portion of the atmoſphere is called oxygene.

Iron is found in this ſtate in its ores. The proceſs of extracting it from theſe ores principally conſiſts in depriving it of oxygene.

Charcoal has the property of effecting this change. During combuſtion it abſorbs and unites with oxygene, and it will attract the oxygene from iron when theſe ſubſtances are in contact at an elevated temperature. Theſe effects of air and charcoal are very perceptible when tin is kept in fuſion. A grey pellicle is ſoon formed on the ſurface, which has no metallic ſplendour. If this pellicle be taken off, a ſecond is formed, and in this manner the whole of the tin may be converted into a ſubſtance reſembling earth, and known by the name of droſs. By expoſure of the droſs to heat, together with a ſmall quantity of charcoal powder, tallow, or reſin, the oxygene is abſorbed by theſe combuſtible ſubſtances, and the tin becomes reduced to the metallic ſtate.

Charcoal not only poſſeſſes the property of depriving the iron of the air which was united with it, but it is alſo capable of being diſſolved in the iron in a ſtrong heat, and by this ſolution it communicates new properties to it. It changes it into ſteel †.

Crude or caſt iron may be conſidered as a metal not completely reduced, which conſequently retains a portion of the baſis of air, or oxygene, to which it was united in the ore; and as this reduction may be carried farther according to circumſtances, the conſequent variations are among the leading cauſes of the different properties we obſerve in caſt iron. The white caſt iron accordingly holds in ſolution much oxygene and little charcoal; the grey caſt iron on the contrary contains more of this laſt ſubſtance, but is much more perfectly deprived of oxygene. A greater proportion of coal muſt be uſed in the furnace to obtain this laſt. The properties of theſe two kinds of iron depend only on this difference: the former is more brittle and fuſible, but it is eaſy in the refining furnace to deprive it of oxygene by the action of ignited charcoal, which combines with this principle. The ſecond has retained leſs oxygene, but contains much more charcoal. It is ſofter, and preferable for ſuch uſes as require this ſoftneſs; but it is more difficult to convert it into malleable iron, becauſe a larger portion of coal is required to be deſtroyed, and in this ſtate it conſiderably reſiſts combuſtion.

* I have omitted a few political reflections of a temporary nature contained in this memoir.

† Other ingredients enter into ſteel, and are perhaps eſſential to it, particularly phoſphorus. See the analyſis of Vauquelin, Philoſ. Journal, I. 252.

Forged

Forged iron perfectly refined would consist of the metal completely reduced, and containing no foreign substance, not even charcoal. Such iron is not to be met with in the market. The best Swedish iron always contains a portion of oxygene which has escaped the operations of the furnace and the refinery, and it is always contaminated by a dose of charcoal, very small indeed, but which perhaps it is impossible totally to eradicate.

Other circumstances likewise influence the qualities of iron, particularly with respect to the fabrication of steel. This metal, according to the nature of the ores which afford it, may have the defects of being brittle when cold, or brittle when hot. These are respectively called cold-short, or red-short iron. We shall not here discuss the causes which produce these bad qualities*; but shall only remark that such iron, or its ores, affords bad steel, and must therefore be carefully avoided.

Steel is distinguished into three kinds:—natural steel; steel of cementation; and cast steel.

Concerning Natural Steel.

THE steel obtained immediately from the ore by simple fusion, is called natural steel. It is likewise distinguished by the name of German steel, because it comes principally from Germany.

Whether the crude iron shall assume the nature of bar iron, or of steel, depends on circumstances; but these are not difficult to be explained, from the doctrine already laid down.

Grey crude iron is alone proper to afford steel; for which purpose it is requisite that the oxygene it contains should be separated, and the coal from which its grey colour arises should be intimately combined with it. The conversion of the crude iron into steel depends on these processes †.

Hence it follows as a leading rule, that no attempts must be made to convert the white crude iron into steel in this way, notwithstanding it may be capable of affording excellent bar iron. The first operation must be conducted in such a way as to afford grey crude iron, by adding a greater proportion of coal in the charge of the furnace.

The appearance of crude iron is often deceitful with respect to its nature. The grey crude iron in plates or small portions, suddenly cooled, has the colour of the white crude iron. But the nature of these irons may be ascertained by the simple process described at the end of this memoir.

When a proper crude iron is in readiness, it is necessary, in order to convert it into bar iron, that it should be much more exposed to the action of the air by frequent stirring, and by removing the scoriæ; but when steel is desired, it is less exposed, and suffered to remain covered by those scoriæ. In the former process the charcoal is burned by the contact of the air, and the iron is left considerably more pure; but in the second the charcoal is preserved; part of which combines with the oxygene which still remained in the iron, and

* Cold-short iron is afforded by ores which contain a small portion of phosphoric acid, which combines with the metal in the state of phosphorus. Red-short iron, which is much less common than the other, contains arsenic; but it is probable that the other semi-metals may produce the same effect. *Note of the authors.*—Probably the volatile metals may most eminently conduce to this effect. N.

† See Philos. Journal, I. 328.

serves to separate it, while the other portion combines with the iron itself, and gives it the qualities of steel.

The disposition of the hearth or fire-place, and the position of the tuyer or nozle of the bellows, are two objects which require much attention. In order to obtain iron, the fire-place must be larger than for steel, and the tuyer must be inclined so as to direct the blast to the surface of the iron. The hearth is to be filled with charcoal, and the crude iron placed thereon to the level of the upper part of the tuyer. The heat is applied moderately, and by degrees, in order that the iron may not flow, but be kept in the state of a paste. It is to be stirred occasionally with the rake, frequently brought into the direction of the blast, and the scoriæ must from time to time be taken out.

To produce steel, a bed of small or powdered charcoal is to be laid round the fire-place, which must be moistened and rammed down. Light fusible scoriæ are added; the tuyer is usually more inclined, and the fusion more hastily urged, in order that the metal may flow, and immediately sink beneath the scoriæ, which are not removed till the end of the operation.

The same processes are not every where followed: but a little attention serves to show that they are all founded on the same principles; namely, that in producing steel the coaly principle of the iron is not burned, whereas in the production of bar iron the operation is so conducted as to burn that principle. We shall proceed to mention some instances.

In Styria, where good steel is made, the cast iron is reduced into thin plates, which are fused in the refinery. The ordinary masses or loupes, which have been suffered to cool in the furnace, instead of having been drawn off, are also fused for steel, of which they have begun to assume the character during their maceration in the pot, which, with this intention, was lined with charcoal, and wherein they were covered with the scoriæ. The plates as well as these masses, which are previously divided into smaller pieces, are refined with the precautions necessary to determine the formation of steel.

A circumstance which contributes much to the goodness of the steel is, that after it has been drawn out by the hammer, the bars are thrown red-hot into water, and afterwards broken in pieces for the purpose of separating the perfect steel from that which is of the nature of iron. The hard steel is also separated from the soft. Packets or trusses of these are made up, consisting of twelve or fifteen pieces each, observing that the two outer pieces are soft steel. These trusses are welded together, and drawn out again to a small size; by which means the quality of the steel is rendered considerably more uniform. The greatest quantity of German steel, as well as that which is most esteemed, is made in Carinthia. Their processes deserve to be particularly attended to. We shall here give a short account of the particulars from Hassenfratz, who made his observations on the spot, and has communicated them to us.

The crude iron is reduced into thin plates, or leaves, when it is drawn from the smelting furnace. For this purpose a mould, or hemispherical cavity, is prepared before the furnace. It is formed of the scoriæ reduced into very fine powder, and wetted to make them adhere together.

The work is then opened with an iron bar, in order that the scoriæ may flow into the mould, and dissipate its moisture. These are in the next place taken out, and the metal itself is suffered

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to flow at firſt in a ſmall ſtream, and afterwards more ſpeedily. The aperture is enlarged in proportion as it flows out, and at laſt the ſcoriæ fall on the iron, and cover it in the mould. The furnace is then again cloſed, and the blaſt renewed. Water being thrown on the ſcoriæ which occupy the upper portion of the mould, they become fixed, and in this ſtate are removed. A ſecond portion of water is then thrown on the naked ſurface of the metal, which congeals to a ſmall depth. The thin congealed plate is taken off, and a ſecond aſperſion of water is made, which affords a third plate. In this manner the proceſs is continued, until as much of the metal is converted into plates as can be effected during the fluidity of the maſs.

At ſome works the iron is melted in a particular furnace from the pig, for this purpoſe; but this ſecond operation is evidently waſteful both of time and fuel.

The plates are intended to be made into either iron or ſteel.

In the proceſs for making bar iron, the firſt operation conſiſts in roaſting the plates on a hearth, upon which they are arranged; a paſſage being formed with bricks, in order that the wind of the bellows may be directed from one extremity to the other. They are then covered with charcoal, and urged ſtrongly with the bellows. The plates by this roaſting, which deſtroys the charcoal of the caſt iron, begin to aſſume the qualities of bar iron, after which they are carried to the finery furnace. The body of this furnace is more capacious than that which is intended for ſteel. The iron is covered with charcoal and ſcoriæ, and the tuyer is inclined ſo that the blaſt ſtrikes on the plates of metal. When the fuſion is complete, the ſcoriæ are let out, the maſs is frequently turned to expoſe it to the blaſt, and, laſtly, the proceſs being completed, the iron is conveyed to the hammer.

If the object be to form ſteel, the furnace made uſe of is more contracted and deep. It is lined with pulverized charcoal, moiſtened and rendered ſolid by beating. The plates are diſpoſed therein, and covered with ſcoriæ and charcoal. The poſition of the tuyer is nearly horizontal, in order that the ſtream of air may ſtrike the fuel, and not the metal. When the metal begins to aſſume the ſolid ſtate, the coal is taken off, the ſcoriæ are ſuffered to flow out, and ſcales and fragments of ſteel are driven by hammering into the ſoft maſs.

The piece is afterwards melted a ſecond time with the ſame precautions as before; and when the metal is thought to be ſufficiently refined, the ſcoriæ are drawn off, and the maſs is conveyed to the hammer to divide it into ſeveral pieces, which are to be ſeparately forged out.

We ſee that all theſe operations are directed to the means of deſtroying the charcoal of the crude iron, when bar iron is wanted; but when ſteel is required to be made, the metal is not only preſerved from the contact of the air, but the veſſel is lined with charcoal, in order that, by its contact with the fuſed matter, it may ſupply any portion of that principle which may be wanting.

In the foregoing proceſs there are two fuſions of the metal. In the latter it is not only completed by the ſecond fuſion, but it is rendered more homogeneous. This method is excellent, and is perhaps the only means by which an exceedingly good ſteel can be had.

The other part of the proceſs is worthy of much attention, namely, the reduction of the crude iron into plates. When bar iron is wanted, theſe plates roaſt with more facility

 on

on account of the great surface they present to the air. And when steel is wanted, they are more readily fused, and sink beneath the scoriæ, which prevents the charcoal of the iron from being consumed by the action of the air. On the contrary, they absorb what might have been wanting from the lining of the vessel, which is prepared in such a manner as to support itself without being consumed through the whole of the operation.

When the steel has congealed in the furnace, it is taken out and divided into several portions more or less considerable, which are carried to the hammer. Here a separation is made of such portions as are not reduced into steel, but iron, and which occupy the surface of the pieces. Each piece is drawn out into bars, which are reduced into other smaller bars of different dimensions, by separating the softest parts from those which are more hard.

For steel of a superior quality, several bars of the soft and hard kinds are united by welding and forging. The hardest are placed in the middle.

We have shown that, in order to obtain steel from crude iron, it is necessary to have an iron abounding with coal; but there is an excess which is hurtful. The black crude iron, which contains too much coal, affords a steel so brittle as to be of no use. This kind of steel becomes fixed with more difficulty than good steel. When the workman perceives this symptom, he may prevent the bad effect by adding a certain quantity of old iron fragments, which deprives the too steely metal of its excess of coal, and, by incorporating with it, produces an uniform mass of good steel. When the crude iron is of such a nature as to afford brittle steel, it is usual to mix in the refining furnace a quantity of another kind of crude iron, which may modify its quality.

Though iron and steel are distinguishable by very striking qualities, there is, nevertheless, a point of contact at which they are confounded: the softest steel may be considered as a very hard iron, and, in fact, the several kinds of iron differ in hardness by the same principle which constitutes steel. They all retain a small portion of charcoal, which escapes the operation of refining. Those which contain the least are under like circumstances more flexible, soft, ductile, and susceptible of acquiring by the action of the hammer that fibrous form which constitutes what is called the grain of iron. Hence it is that different kinds of bar iron are sometimes obtained from the same crude iron, though the operation is apparently the same. It is sufficient for this effect that the inclination of the tuyer be changed.

Concerning Steel obtained by Cementation.

THE steel of cementation is formed by means of a cement, with which bars of forged iron are surrounded in a case disposed in the middle of a furnace, where they are subjected to a strong heat.

We must repeat that the good quality of the iron is a condition indispensable for obtaining good steel. It is of importance to choose the best kind; and the English, who almost exclusively prepare the steel of cementation, retain for that object all the iron of Roslagia, which is the best iron of Sweden, and for which they pay a high price.

It is not enough that the iron should contain no noxious principle. It is also necessary that it should be forged with care, and its parts well united. For if it contain flaws or clefts

clefts within the bars, they become much more perceptible when the iron has acquired the nature of ſteel; and it would not be practicable to unite them perfectly, becauſe the parts of ſteel are much leſs diſpoſed to weld and adhere together than thoſe of iron. We have had convincing proofs in our own experiments, that the irons of France of good quality, ſuch as thoſe of the ci-devant Berry, afford only a bad ſteel when cemented in the ſtate they uſually are delivered in from the forge; but the ſame iron, after having been carefully forged and hammered, formed ſteel equally good with that which had been made at the ſame time from an excellent iron of Sweden. In another experiment the ſteel prepared with iron of the ci-devant comté de Foix, which had been well forged, produced ſteel of a quality equal to that which had been obtained in the ſame operation with Swediſh iron.

Hence it reſults, 1. That the beſt Swediſh iron owes its property of forming good ſteel, leſs to any particular quality of the ore than to the care with which it is forged and ſubmitted to the action of the hammers: 2. That we poſſeſs in France irons capable of affording good ſteel, provided care be taken that they be well forged; but the mere neglect in this operation may prove fatal to a plan in other reſpects well conducted.

The firſt attention which ought therefore to be paid in the attempt to manufacture ſteel is to procure good iron, to examine whether it be well forged; and in caſe this operation has not been ſufficiently attended to, it muſt be forged and made ſound before it is ſubjected to cementation.

It has long been ſuppoſed that the cement proper for the ſteel-making proceſs ought to contain ſaline, inflammable, fat or ſulphureous parts, which were ſuppoſed to penetrate the iron and change it into ſteel. Hence have ariſen many pretended ſecrets, which have diverted the attention of thoſe who have engaged in undertakings of this kind under the guidance of ignorant pretenders. There are no ſecrets in the compoſition of the cement. The Engliſh uſe no material but the charcoal of wood reduced to powder; and in fact the only eſſential condition is, that the iron ſhould become impregnated with the very ſubſtance of the charcoal uniformly to its centre.

When the bars or plates of iron which are to be converted into ſteel are ready for the furnace, they are cut to the length of the caſe or crucible in which the cementation is to be made. A bed of charcoal powder, ſifted through a coarſe ſieve, and ſlightly wetted, is laid in the bottom of the caſe. Upon this is placed a row of iron bars at a little diſtance from each other. This firſt layer of iron is then covered with a bed of charcoal powder, which fills the ſpaces within the bars, and riſes to the height of half an inch above them. A new range of bars is then laid and covered with charcoal as before, and in this ſucceſſive way the operator proceeds till the caſe is full. The laſt row is covered with charcoal powder, over which is laid a bed of ſand to cover its ſurface entirely, and prevent its being deſtroyed by combuſtion. The ſand muſt be moiſtened and well preſſed together in the form of a roof, riſing higher than the ſides of the caſe, ſo as to be ſeveral inches thick in the middle.

When the preparation or charging of the caſe is finiſhed, the furnace is diſpoſed for making the fire, which is gradually increaſed, and muſt be kept up for a longer or ſhorter time according to the quantity of ſteel, and conſequently according to the ſize of the caſe. At Newcaſtle, where between twenty-five and thirty thouſand weight of ſteel is cemented in two caſes contained in a furnace, the operation laſts five days and five nights. At one

of

of the extremities of the furnace as well as of the case, it is usual to form a hole, by which a bar may be taken out when it is supposed that the cementation may be sufficiently advanced. The workman judges from the colour, and the blisters on its surface, whether the steel be perfect. If he cannot depend on his judgment in this respect, trial is made of this steel by hardening and breaking it. If the cementation have not penetrated as far as the centre, it is easy to distinguish, by the fibrous fracture, that part which still retains the nature of iron.

When the steel is taken out of the cementing furnace, its surface is covered with inequalities and blisters, whence it is called blister steel. In this state its fracture presents very large facets, and resembles brittle iron of a bad quality. Before it is brought to market it is usually forged into flat bars seven or eight lines broad; after which it is suffered to cool in the air without plunging it in water. By this treatment its grain becomes much closer.

As the extremities of the bars thus converted into steel are usually flawed and less perfect, they are cut off and forged together in faggots. This steel is used for instruments of agriculture. If the fire have not been sufficiently active, or kept up for the proper time, the bars are not cemented to the centre; whence they become of unequal hardness, especially if they be not very carefully forged. When the fire has been too intense, the steel becomes too brittle, and difficult to be managed on account of its having dissolved too large a quantity of charcoal. Yet it is impossible to establish any rule for the management of the fire, because it must vary according to the form and size of the furnace, the number and thickness of the bars, and the nature of the fuel.

The form and magnitude of the furnaces vary considerably in the different works where iron is cemented. The objects to be aimed at are, to give the furnace a degree of solidity which shall enable it to resist a great number of operations, to cause the flame and heat to circulate equally on all sides of the case, and to produce the greatest quantity of heat with the smallest expence of fuel.

One very important observation respecting the extent of dimensions which may be given to these furnaces is, that no advantage, or at least very little, in the consumption of fuel is obtained by enlarging these dimensions, because it is necessary that the whole of the heat should be suffered to dissipate at the end of each operation. The case is very different in other manufactories where the accumulated heat may serve for successive processes; for the whole of such fuel as is employed in raising the temperature to the necessary degree in cases of interruption would be entirely lost.

Prudence demands, that he who is desirous of improving or extending the arts should not blindly be led away by the seduction of projects. It is proper to begin the operations on a small scale, in order to render the practice familiar, before furnaces of a certain magnitude are constructed *.

(To be concluded, with Annotations, in our next.)

* Reference is here made in the original to drawings of furnaces; one contrived by Jars for cementing three or four hundred weight of steel; another of the furnace at Newcastle; another heated by wood, together with some designs relative to the manipulations at Carinthia. None of these, however, are annexed to the memoir. N.

IV.

Observations Chemical and Economical on various Subjects *.

1. M. TROMSDORFF, Professor at Erfurt, has observed that sulphurated hydrogenous gas takes fire and burns with a strong flame by means of the nitrous acid.

2. M. Linck, Professor at Rostoc, finds that three parts of nitrous gas, and two of hydrogene gas, obtained by sulphuric acid and iron, are scarcely or not at all diminished when exposed to day-light over water. Common air is not more diminished by this admixture kept a long time: but the mixture itself of these two gases is diminished by the addition of new portions of nitrous gas. M. Linck concludes from this observation, that part of the oxygene of the nitrous gas combined with the hydrogene and formed water, and that the remaining oxygene and azote formed a mixture similar to the air of the atmosphere.

Citizen Vauquelin made a similar remark ten years ago on nitrous gas placed over a solution of the hydro-sulphuret of lime. The diminution of the gas was considerable.

3. The urine of animals which feed on vegetables does not contain phosphoric acid, but an acid of a vegetable nature. On this passage C. Vauquelin remarks, that Rouelle announced this fact twenty years ago, and that C. Fourcroy and himself have lately proved it by a great number of experiments, which have moreover shewn that the acid which supplies the place of the phosphoric in these animals is the benzoic.

On this occasion it may be remarked, that the vegetable kingdom affords phosphorus; that the bones which are produced and grow in animals feeding only on vegetable food contain this substance; whence it appears probable that their urine is not at all times divested of phosphoric acid. M. Giobert in his memoir on phosphorus (Annales de Chimie, xii. 23.) affirms that the urine of horses is nearly as proper for his process as that of men; that is to say, that it affords nearly as much phosphorus. But he does not positively relate any experiment to this effect.

4. A German correspondent of the work before us affirms, that the blowing machines or bellows for the iron works in the Hartz, are cubical boxes of wood, which are more easily made than the iron cylinders made use of in England, and that they are very advantageous in the use. From various accounts there is reason to think, that the density and velocity of the stream of air from our iron cylinder worked by a steam engine are greater than has ever been afforded by the wooden bellows or other blowing engines formerly in use. The height to which this air will support a column of water is between six and seven feet, or at a medium near six inches of mercury.

5. Attempts have been made in Saxony, and particularly at Freyberg, to increase the quantity of water made use of to move the machines in that country. It has been found convenient to establish pumps worked by the wind, to raise a portion of the water which passes through the galleries, or is collected in the works. It is not intended to make use of this inconstant first mover to clear the mines of water, but simply to fill the reservoirs which work the hydraulic machines, at the same time that the secondary advantage of assisting to keep the mines clear is obtained. By this means the power of the wind, changeable as it is, may be rendered steadily useful. The celebrated Leibnitz first thought of this con-

* Journal des Mines, No. 29

trivance,

trivance, and endeavoured, though at that time without ſucceſs, to carry it into effect. I apprehend that his reſervoir may not have been ſufficiently capacious. Attempts have been made in England, to render the action of ſmall ſtreams more ſteady and conſtant by the intervention of a reſervoir, which ſhould retain a large portion of the water when wet weather rendered it plentiful, and ſupply the defect at ſuch times as the water failed for want of ſufficient rain.

6. An experiment has been made in the large way at the ſalt-work of Artern, ſituated in the circle of Thuringia, dependent on the electorate of Saxony, on the poſſibility of obtaining ſea-ſalt merely by the heat of the ſun, after having brought the ſalt water to as high a degree of concentration as the proceſs of graduation is capable of affording. This ſalt work was the firſt eſtabliſhment of the kind in Saxony, by Mr. Borlach, to whom the undertakings of this nature are ſo much indebted ; and it will probably have the honour of being the firſt in which this new proceſs ſhall ſucceed. Experiments on a ſmaller ſcale have already afforded the higheſt hopes of ſucceſs. Thoſe which have been attempted in the large way, though at the end of the warm weather, have afforded encouraging reſults.

For this purpoſe a number of veſſels of wood have been placed in a field upon poſts, at the height of five or ſix feet from the ground. They can be covered or uncovered in an inſtant by a moveable roof made of thin boards, accordingly as the weather is clear or rainy. Though the ſummer was nearly over when the experiments began, ſalt was obtained in this manner by the mere heat of the ſun ; and this ſalt was much purer, and of a more lively and agreeable taſte, than that which is obtained by evaporation in boilers. There is every reaſon to expect that the whole of the ſalt which can be obtained at theſe works, will be ſeparated in this manner without the uſe of any combuſtible. A great number of theſe caſes are accordingly prepared, to give all the neceſſary activity to this method of operating next year.

Citizen Charles Coquebert, in a note on this ſubject, remarks that the celebrated Haller publiſhed, in the Memoirs of the French Academy for the year 1764, a ſet of experiments on the evaporation of ſalt-waters made at the works in the canton of Berne, of which he was the director; and adds, that the experiments are intereſting, but that the economical calculations are grounded on ſuch erroneous foundations, that they would ſerve only to miſlead thoſe who from the reputation of the author might uſe his calculations relative to any undertaking in the large way.

V.

An Analyſis of the Earthy Subſtance from New South Wales, called Sydneia, or Terra Auſtralis. *By* CHARLES HATCHETT, *Eſq. F.R.S.**

IN 1796, the Right Hon. Sir Joſeph Banks, P.R.S. favoured me with a ſpecimen of the Sydneia, which had been lately brought to England. A portion of this I ſoon after examined,

* From the Philoſ. Tranſ. 1798. The introductory part of Mr. Hatchett's paper conciſely ſtates the reſults of Wedgwood's paper (from which an extract is copied in Philoſ. Journ. I. 405);—that Profeſſor Blumenbach, in

ed, in a cursory manner, by muriatic acid, but did not obtain any precipitate when water was added to the filtrated solution.

Upon mentioning this circumstance, and expressing a desire to examine this substance with more accuracy, Sir Joseph Banks, with his usual readiness to promote every scientific enquiry, not only permitted me to take specimens from different parts of the box which contained the earth already mentioned, but (that every doubt might be obviated) gave me about 300 grains which remained of the identical substance examined by Mr. Wedgwood.

Upon these the following experiments were made; and, to distinguish them, I shall call the first, No. 1, and that examined by Mr. Wedgwood, No. 2.

SECT. II.

Analysis of the Sydneia, *No.* 1.

THE Sydneia, No. 1, is in masses and lumps, of a pale greyish white, intermixed with a few particles of white mica, and also occasionally with some which are of a dark grey, resembling graphite or plumbago.

It easily crumbles between the fingers, to a powder nearly impalpable, which has rather an unctuous feel.

Small fragments of vegetable matter are also commonly found intermixed with it; and the general aspect is that of an earthy substance which has been deposited by water.

Experiment 1.—400 grains were put into a glass matrass, and one quart of distilled water being added, the whole was boiled to one-fourth.

The liquor was then filtrated, and a portion being examined by the re-agents commonly used, afforded no trace of matter in solution. The remainder was then evaporated, without leaving any residuum.

Experiment 2. About 200 grains of the earth, rubbed to a fine powder, were put into a glass retort, into which I poured three ounces of concentrated pure muriatic acid. The retort was placed in sand, and the acid was distilled, till the matter in the retort remained dry. Two ounces of muriatic acid were again poured on it, and distilled as before, till only one fourth remained. The whole was then put into a matrass, which was placed in an inclined position, so that, when the earth had subsided, the liquor might be decanted without disturbing the sediment.

When it had remained thus for 12 hours, the acid was carefully poured into a glass vessel: but, as I observed that it was not so perfectly transparent as before it had been thus employed, I suffered it to remain 24 hours, but did not perceive any sediment. Half of this liquor was diluted with about twelve parts of distilled water, and, after a few hours, a very small quantity of a white earth subsided.

in his Handbuch der Naturgeschichte, p. 567, 568, mentions that he had examined a portion of this earthy substance, by means of muriatic acid after the manner of Wedgwood, and obtained a slight precipitate;—that M. Klaproth had also examined it, whose results he likewise gives (for which see the page of our Journal last mentioned);—and that the identity of the subjects examined by Wedgwood and Klaproth had been much questioned by me. The author then proceeds to relate the history and particulars of his own analysis, of which the words of the text are an exact copy. N.

This however did not appear to me to be a precipitate caused by a change in the chemical affinities, but rather an earthy matter which had been suspended in the concentrated acid, and afterwards deposited, when the liquor was rendered less dense by the addition of water. To ascertain this, I poured the remaining portion of the concentrated liquor on a filter of four folds: it passed perfectly transparent, and, although diluted with twenty-four parts of water, it remained unchanged, and as pellucid as before. I now filtrated the former portion, and added it to that already mentioned.

It was then evaporated to dryness, and left a pale brownish mass, which was dissolved again, by digestion, in the smallest possible quantity of muriatic acid.

Water was added, in a very large proportion, to this solution, without producing any effect; I then, by prussiate of potash, precipitated a quantity of iron, which was separated by a filter.

The clear solution was then saturated with lixivium of carbonate of potash, and a white precipitate was produced, which was collected and edulcorated. This, when digested with diluted sulphuric acid, was dissolved; and the superfluous acid being driven off by heat, boiling water was poured on the residuum, and completely dissolved it.

To this solution some drops of lixivium of potash were added, and, by repeated evaporations, the whole formed crystals of alum.

From the above experiment it appeared, that the muriatic acid had only dissolved some alumine and iron; but, in order to satisfy myself more completely in respect to the component parts of this substance, I made the following analysis.

Analysis. A. 400 grains were put into a glass retort, which was then made red-hot during half an hour. Some water came over, and the earth afterwards weighed 380.80 grains, so that the loss amounted to 19.20 grains. The greater part of this loss was occasioned by the dissipation of the water imbibed by the earth; to which must be added, the loss of weight caused by the combustion of a small portion of vegetable matter.

B. The 380.80 grains were rubbed to a fine powder, and being put into a glass retort, 1470 grains of pure concentrated sulphuric acid were added. The retort was then placed in a small reverberatory, and the fire was gradually increased, till the acid was distilled over: it was then poured back on the matter in the retort, and distilled as before, till a mass nearly dry remained.

On this, boiling distilled water was repeatedly poured, until it no longer changed the colour of litmus paper, and was devoid of taste. The undissolved portion was then dried, and made red-hot; after which it weighed 281 grains.

C. I now mixed the 281 grains with 300 grains of dry carbonate of potash, and exposed the mixture to a strong red heat, in a silver crucible, during four hours. The mass was loose, and of a greyish white: it was softened with water, and, being put into a retort, sulphuric acid was added to a considerable excess. The whole was then distilled to dryness; and when a sufficient quantity of boiling water had been added, it was poured on a filter, and the residuum was well washed: it was then made red-hot, and afterwards weighed 274.75 grains.

D. The solutions of B and C were added together, and were much reduced by evaporation. Pure ammoniac was then employed to saturate the acid, and a copious loose precipitate

pitate of a pale yellowiſh colour was produced; which, collected, edulcorated, and made red-hot, weighed 103.70 grains.

E. The filtrated liquor of D was again evaporated; and carbonate of potaſh being added, a ſlight precipitation of earthy matter took place; which, by the teſt of ſulphuric acid, proved to be ſome alumine which had not been precipitated in the former experiment: this weighed 1.20 grain.

F. The 103.70 grains of D were completely diſſolved when digeſted with nitric acid, excepting a ſmall reſiduum of ſiliceous earth, which weighed 0.90 grain.

G. The nitric ſolution was evaporated to dryneſs, and a ſecond portion of the ſame acid was added, and in like manner evaporated. The reſiduum was then made red-hot, and digeſted with diluted nitric acid, which left a conſiderable portion of red oxyde of iron. The ſolution was again evaporated, and the reſiduum, being treated as before, again depoſited ſome oxyde of iron, much leſs in quantity than the former.

The whole of the oxyde was then heated with wax in a porcelain crucible, was taken up by a magnet, and weighed 26.50 grains.

H. The nitric ſolution of G was ſaturated with ammoniac, and a looſe white precipitate was formed; which, edulcorated and made red-hot, weighed 76 grains.

I. Theſe 76 grains were diſſolved when digeſted with diluted ſulphuric aid; and, when the exceſs of acid had been expelled by heat, the ſaline maſs was diſſolved in boiling water. To this ſolution I added ſome lixivium of potaſh, and, by gradual and repeated evaporations, obtained the whole in regular octoedral cryſtals of alum.

K. The 274.75 grains of C now alone remained to be examined. They appeared to conſiſt of ſiliceous earth, mixed with the dark grey ſhining particles already mentioned; but, as I ſhall deſcribe, in the following experiments, the proceſs by which theſe were ſeparated, I ſhall now only ſay that they amounted to 7.50 grains.

L. The earth with which the abovementioned particles were mixed weighed 267.25 grains. This earth was white, and arid to the touch: when melted with two parts of ſoda, it formed a colourleſs glaſs; and with four parts of the ſame it diſſolved in water, and formed a *liquor ſilicum*: it was therefore pure ſiliceous earth or ſilica.

The ſubſtance here examined was compoſed therefore of the following ingredients:

		Grains.
Pure ſiliceous earth or ſilica -	F.	0.90
	L.	267.25
Alumine - - - - -	E.	1.20
	H.	76 .
Oxide of iron - - - - -	G.	26.50
Dark grey particles - -	K.	7.50
Water and vegetable matter -	A.	19.20
		398.55

The foregoing analyſis was repeated ſeveral times, and always with ſimilar reſults; excepting that, as I had taken the ſpecimens from different parts of a large quantity, I found that the proportions of the ingredients were not conſtantly the ſame: that of the ſiliceous

earth,

earth, for example, was ſometimes greater, and the alumine and iron proportionably leſs. Some ſpecimens were alſo nearly or totally deſtitute of the dark grey ſhining particles: in ſhort, every circumſtance was ſuch as might be expected from a mixed ſubſtance, which, from the nature of its formation, cannot have the ingredients in any fixed proportion *.

As this ſubſtance agreed in its general characters, for the greater part, with that deſcribed by Mr. Wedgwood, and as it was indiſputably brought from the ſame place, there appeared every reaſon to believe that the nature of both was the ſame; but, to obviate as much as poſſible any doubt or objection, I determined to repeat the experiments, and the analyſis, on that portion which remained of the identical ſubſtance examined by Mr. Wedgwood, and which from that period had been reſerved by Sir Joſeph Banks, who kindly favoured me with it for this purpoſe.

SECT. III.

Analyſis of the Sydneia, *No.* 2.

THIS ſubſtance, as has already been mentioned, conſiſts of a white tranſparent quartzoſe ſand, a ſoft opaque white earth, ſome particles of white mica, and a quantity of dark lead-grey particles, which have a metallic luſtre.

The Sydneia, No. 2, appears chiefly to differ from No. 1, by being more arenaceous, and by a larger proportion of the dark grey particles. Many experiments, ſimilar to thoſe made on No. 1, already deſcribed, were made on this ſubſtance, with pure concentrated muriatic acid; but, as none of theſe afforded any appearance of a precipitate by the means of water, I do not think it neceſſary to enter into a circumſtantial account of them, and ſhall proceed therefore to the analyſis.

A. 100 grains were expoſed to a red heat, in a glaſs retort, and, after half an hour, were found to have loſt in weight 2.20 grains.

B. The 97.80 grains which remained were mixed with 300 grains of dry carbonate of potaſh, and the mixture was expoſed to a ſtrong red heat, in a crucible of ſilver, during three hours.

When cold, the maſs was ſoftened with water, and was put into a glaſs matraſs. I then added three ounces of pure concentrated muriatic acid, and digeſted it for two hours in a ſtrong ſand heat. Boiling water was then added; and the whole being poured on a filter, the reſiduum was edulcorated, dried, and made red-hot: it then weighed 85.50 grains.

C. The filtrated ſolution was evaporated to one fourth; and pure ammoniac being added, a precipitate was formed, which, after a red heat, weighed 10.70 grains.

D. One ounce of muriatic acid was poured on the 10.70 grains, in a matraſs, which was then heated. The whole of the 10.70 grains was diſſolved, excepting a ſmall portion of ſiliceous earth, which weighed 0.30 grain.

* The deſcription given by Mr. Klaproth convinces me that his experiments were made on a portion of this ſubſtance. Moreover, when my late friend Mr. Haidinger was in London, I gave him ſome of this earth for his collection; ſo that, whether Mr. Klaproth made his experiments on that which had been received by Mr. Haidinger from Sir Joſeph Banks, or from myſelf, it is not leſs certain that he operated on that which might be regarded as the genuine *Sydneia.*

E. The

E. The muriatic solution was then reduced, by evaporation, to about one fourth; to which I added a large quantity of distilled water, which did not however produce any change. I then gradually added a solution of pure crystallized prussiate of potash, and heated the liquor till the whole of the iron was precipitated; after which, ammoniac precipitated a loose white earth, which, edulcorated and made red-hot, weighed 7.20 grains. The iron precipitated by the prussiate may therefore be estimated at 3.20 grains.

F. The 7.20 grains of the white earth were digested with sulphuric acid, and, after the excess of acid had been expelled by heat, boiling water was poured on the saline residuum. The solution was then gradually evaporated, with the addition of a small portion of lixivium of potash, and afforded crystals of alum, without a trace of any other substance.

G. I now proceeded to examine the 85.50 grains of B. These appeared to consist of siliceous earth, or fine particles of quartz, mingled with a considerable quantity of the dark grey shining particles.

Mr. Wedgwood was of opinion that these were a peculiar species of plumbago or graphite. Professor Blumenbach, on the contrary, regards them as molybdæna: and Mr. Klaproth believes them to be *eisenglimmer* or micaceous iron ore.

When rubbed between the fingers, they leave a dark grey stain, and the feel is unctuous, like that of plumbago, or molybdæna: the traces which they make on paper also resemble those of the abovementioned substances, but the lustre of the particles approaches nearer to that of molybdæna.

In order therefore to determine whether or not they consisted totally or partially of molybdæna, I put the 85.50 grains into a small glass retort, and added two ounces of concentrated nitric acid. The retort was then placed in a sand heat, and the distillation was continued till the matter remained dry. The acid was then poured back into the retort, and distilled as before; but I did not observe that the grey particles had suffered any change, nor were nitrous fumes produced, as when molybdæna is thus treated.

To be more certain, however, I digested pure ammoniac on the residuum; and, having decanted it into a matrass, I evaporated it to dryness, without perceiving any vestige of oxyde of molybdæna, or indeed of any other substance.

It was evident, therefore, that molybdæna was not present; and, as the general external characters and properties corresponded with those of plumbago, I was inclined to believe that these were particles of that substance, and not micaceous iron, as Mr. Klaproth imagined. To determine this, the following experiment was made:

H. 200 grains of pure nitre in powder were mixed with the 85.50 grains, and the mixture was gradually projected into a crucible, made strongly red-hot. A feeble detonation took place at each projection; and, after a quarter of an hour had elapsed, the crucible was removed.

When cold, the mass was porous and white, without any appearance of the dark grey particles. Boiling water was poured on it; and the whole being put into a matrass, one ounce of muriatic acid was added, and digested with it in a sand heat. By evaporation it became gelatinous: it was then emptied on a filter, and, being well washed, dried, and made red-hot, weighed 75.25 grains.

The appearance of this was that of a white earth, arid to the touch. When melted

with two parts of soda, a colourless glass was formed; and, with four parts of the same, it was soluble in water, and produced *liquor silicum:* it was therefore pure siliceous earth.

I. The filtrated liquor was saturated with ammoniac; and, upon being heated, a few brownish flocculi were precipitated, which, when collected and dried, weighed 0.40 grain. This precipitate was dissolved in muriatic acid, and was again precipitated by prussiate of potash, in the state of Prussian blue.

The liquor from which the flocculi of iron had been separated was then examined, by adding carbonate of potash, and, lastly, by being evaporated to dryness; but it no longer afforded any earthy or metallic substance: so that, by the process of detonation with nitre, the 85.50 grains afforded 75.25 grains of pure siliceous earth, with 0.40 grain of iron; and, as the dark grey substance was destroyed, excepting the 0.40 grain of iron above mentioned, and as 9.85 grains of the original weight of 85.50 grains were dissipated, there can be no doubt but that this substance, amounting to 10.25 grains, was carburet of iron or plumbago; especially as some experiments which I purposely made, on that from Keswick in Cumberland, were attended with similar results.

It is also evident, that these particles could not be *eisenglimmer*, or micaceous iron, as nitre has little or no effect on that substance, when projected into a heated crucible.

In a subsequent experiment on the same, the crucible was removed immediately after the last projection; and I then observed that an effervescence, with a disengagement of carbonic acid, took place, upon the addition of the muriatic acid, as is usual when pure plumbago is decomposed by nitre, and that less of the gelatinous matter was formed by evaporation.

The cause of this difference was evidently the duration of the red heat; for, in the first instance, the alkali developed by the decomposition of the nitre had time to unite with the siliceous earth, so as, when dissolved, to form *liquor silicum*; but, in the second experiment, a portion of alkali remained combined with the carbonic acid, produced by the carbon of the decomposed plumbago.

The produce of 100 grains by this analysis was,

		Grains.
Silica	D.	0.30
	H.	75.25
Alumine	F.	7.20
Oxide of iron	E.	3.20
Graphite or plumbago	I.	10.25
Water	A.	2.20
		98.40

Mr. Wedgwood says, that sulphuric acid cannot dissolve the precipitated earth, and has but little effect on the mixed substance, even when distilled to dryness; but, from the preceding experiments, I had reason to believe that the aluminous earth and iron would be separated by reiterated distillation; I therefore repeated the analysis in the following manner.

Second Analysis of the Sydneia, *No.* 2.

A. 100 grains of the earth were put into a glass retort, upon which 400 grains of pure concentrated sulphuric acid were poured. The retort was placed in a small reverberatory, and

and the fire was continued till a dry maſs remained. 400 grains of the acid were again poured in, and diſtilled as before. Upon the dry maſs boiling water was poured, and the whole was then emptied on a filter, and edulcorated. The reſiduum, after a red heat, weighed 87.75 grains, and conſiſted of ſiliceous earth, mixed with ſome mica, and with particles of plumbago.

B. The filtrated ſolution, by ammoniac, afforded a precipitate, which weighed 9.50 grains; and, being examined, as in the former experiment, yielded 6.50 grains of alumine, and 3 grains of oxide of iron.

The plumbago was ſeparated from the ſiliceous matter, in the manner already deſcribed, and amounted to about 10 grains.

By this analyſis I obtained,

	Grains.
Silica and mica - -	77.75
Alumine - - -	6.50
Oxide of iron - - -	3
Plumbago - - -	10
	97.25

It appears therefore that the Sydneian earth, when treated with ſulphuric acid, is capable of being for the greater part decompoſed; and Mr. Wedgwood probably did not ſucceed, becauſe his proceſs was in ſome reſpect different, or that the diſtillation was not ſufficiently repeated.

I have not thought it neceſſary to be more circumſtantial in the account of this ſecond analyſis, as the operations were ſimilar to thoſe of the former.

SECT. IV.

THESE experiments prove, that the earthy ſubſtance called *Sydneia*, or *terra auſtralis*, conſiſts of ſiliceous earth, alumine, oxide of iron, and black lead or graphite.

The preſence of the latter appears to be accidental, and it probably was mixed with the other ſubſtances at the time when they were tranſported, and depoſited, by means of water; for this appears evidently to have been the caſe, from the general characters of this mixed earthy ſubſtance.

The quartz and mica, which are ſo viſible, indicate a granitic origin; and the ſoft white earth has probably been formed by a decompoſition of feldt ſpar, ſuch as is to be ſeen in many places, and particularly at St. Stephen's in Cornwall. The granitic ſand which covers the borders of the *Mer de Glace*, at Chamouni, in Savoy, alſo much reſembles the *terra auſtralis*, excepting that the feldt ſpar is not in a ſtate of decompoſition: in ſhort, the general aſpect, and the analyſis, concur to prove, that the *Sydneia* has been formed by the diſintegration and decompoſition of granite, or *gneiſs*.

Mr. Wedgwood's experiments are ſo circumſtantial, that had I only examined the earth laſt brought to England, I ſhould have ſuppoſed, with Mr. Nicholſon, that I had operated on a different ſubſtance; but, as I had an opportunity to examine, by analyſis, a portion of the ſame earth on which Mr. Wedgwood made his experiments, and as I received it from

Sir

Sir Joseph Banks, the same gentleman who had furnished Mr. Wedgwood with it, no suspicion can be entertained about its identity.

Some of the experiments which I have related, and which prove that some of the finer earthy particles remained suspended in the concentrated muriatic acid, and were precipitated when the acid was diluted with water, appear in some measure to account for the mistake which has been made, in supposing that a primitive earth, before unknown, was present; but this alone will not account for many of the other properties mentioned by Mr. Wedgwood: such as,

1st. The repeated and exclusive solubility in the muriatic acid, and subsequent precipitation by water.

2dly. The butyraceous mass which was formed by evaporation. And

3dly. The degree of fusibility of the precipitated earth.

These, indeed, I can by no means explain, but by supposing that the acids used by Mr. Wedgwood were impure. This supposition appears to be corroborated by a passage in Mr. Wedgwood's paper, where he says, "Here the Prussian lixivium, in whatever quantity it was added, occasioned no precipitation at all, (only the usual blueishness arising from the iron always found in *the common acids*.")* Now if (as it seems from this expression) Mr. Wedgwood employed the common acids of the shops, without having previously examined and purified them, all certainty of analysis must fall, as the impurity of such acids is well known to every practical chemist †: but whether this was the cause, or not, of the effects described by Mr. Wedgwood, I do not hesitate to assert, that the mineral which has been examined does not contain any primitive earth, or substance possessing the properties ascribed to it, and consequently, that the Sydneian genus, in future, must be omitted in the mineral system.

VI.

The Method of making strong Artificial Magnets. By M. Coulomb‡.

I SHALL here present the methods which I have found successful in constructing artificial magnets of very great force at a moderate expence. * * * * When a steel rod or plate is required to be rendered magnetic, and two bars are used for this purpose, it is obvious that it must be of advantage to cause the poles of these bars to act in conjunction with each other. This has given rise to the method of the double touch. Fig. 1, Plate IV. shows the former practice of this method. If the bar n s be required to be impregnated, the two bars SN, S'N', were placed vertically at the distance of seven or eight lines from

* Philosophical Transactions, vol. lxxx. part ii. p. 313.

† It appears from Wedgwood's paper, that nearly one fifth part of the mineral was taken up by muriatic acid, and that his solution was reckoned to have about six grains of the soluble matter to three ounces of the acid. From the experimental process of boiling, it seems probable that the actual quantity of acid made use of, bore an higher proportion to the matter taken up. If we admit the supposition of impurity in Wedgwood's acid, the quantity of matter precipitable by water was probably less than two grains in the ounce: and after rejecting the Sydneian earth, as we undoubtedly must, it may perhaps be an object worthy of enquiry to determine what that substance was in which Wedgwood observed the peculiar properties related in his paper. N.

‡ Journal de Physique, xliii.

each

each other, more or lefs according to their force; the points S and S′ reprefenting the fouth, and the points N, N′ the north poles. In this fituation the two bars were moved from one end to the other of the bar n s.

M. Æpinus has remarked, that in this method the centre of action of the two magnets NS, N′S′ being neceffarily placed at fome diftance from their extremities at the point u for example, the action on the points of the bar n s comprehended between the two bars is made very obliquely, and confequently does not communicate as much magnetifm as the fubject is capable of receiving. Whence, inftead of placing the two bars upright in this operation, M. Æpinus advifes that they fhould be inclined, as in fig. 2; and in this pofition moved from one end of the bar to the other.

I have, in fact, found by the magnetic balance defcribed at the beginning of this memoir*, that the method of M. Æpinus is preferable to the other; but I have alfo obferved, that it does not give the needles the perfect faturation of magnetifm, and that frequently when the needle is of confiderable length, feveral poles are formed on the intermediate parts, the action of which is indeed fmall, but neverthelefs perceptible. I attribute thefe to the particular action of each magnet, which tends to produce on the points paffed over by the magnets an effect contrary to that which is defired. In our figure 2, the pole S for example being placed upon the needle, tends at the fame time to give to the point q, which is placed under the bar, the fame kind of magnetifm as at the point u; that is to fay, on the hypothefis of two magnetical fluids capable of moving towards the extremities of the needle, if the point u be drawn towards the point n, the point q which is near it will be drawn towards the point s, after this point q fhall have been paffed by both magnets. In my hypothefis, in which the magnetic fluid is not capable of moving, except in the integrant parts, the molecules u and q, which are near each other, tend to become magnetized in oppofite directions; and muft produce a diminution of magnetifm towards the extremities of the needle, where the magnetic fluid muft be moft condenfed; a circumftance which may produce feveral poles in very long needles, as is proved by experience. This obfervation, which neceffarily refults from the accurate meafures afforded by my experiments, obliged me to depart from the method of M. Æpinus. The following is that which, after various trials, has proved by the magnetic balance to be the moft advantageous.

In my operation I ufe four very ftrong magnets impregnated by a firft procefs, which I fhall prefently defcribe. I place my two ftrongeft magnets (fig. 3.) NS, NS, on an horizontal plane in one right line, at fuch a diftance that they may be a few lines nearer to each other, than the length of the needle n s intended to be magnetized. I afterwards take the two magnets N′S′, and inclining them as in the method of Æpinus, I place them firft on the middle of the needle, or with their poles nearly in contact. I then draw each magnet, without changing its inclination, to the extremity of the needle, and repeat this operation five or fix times on each face of the needle. It is clear that in this operation the poles of the needle n s remain fixed and invariable at the extremities of the needle, by means of the two ftrong magnets NS on which it refts. The effect produced by thefe can only be

* The excellent and well known method of Coulomb of meafuring the forces of electricity and magnetifm, is by fufpending an horizontal lever or bar by a fine wire at the point of fufpenfion; which bar being turned caufes the wire by its torfion to exert a determinable force againft the action intended to be meafured. N.

augmented by the action of the two superior magnets, which concur in magnetizing all the particles of the needle in the same direction.

As the needle n s, placed between the two large magnets in the preceding operation, acquires bythe joint action of the four bars a degree of polarity which is more than it can preserve when separated from them, it follows that at the moment of this separation the needle loses part of the magnetism it derived from those forces, and that its magnetism diminishes until the magnetic action of the whole needle on each of its parts is in equilibrio with the coercive force. Hence, upon separating the needle from the magnets, it is found to be saturated with magnetism.

I have found likewise, that in this method of magnetizing, there is a greater certainty of giving to both surfaces of needles, intended to determine the magnetic meridian, an equal degree of magnetism; a circumstance deserving of the greatest attention in the construction of compasses, if the needle be suspended with its broadest surface parallel to the horizon.

The Construction of Artificial Magnets.

I TAKE fig. 4. thirty bars of steel hardened and tempered to the temper of a spring * 5 or 6 lines broad, 2 or 3 lines thick, and 36 inches long. The blades of fencing foils, such as are found in the shops, make pretty good magnets. English sheet steel † (la tôle d'acier d'Angleterre) cut into pieces one inch wide, hardened and lowered to spring temper, is preferable. When each compound magnet is to contain no more than 15 or 20 pounds of steel, it is sufficient to make the bars 30 or 36 inches long.

I magnetize each bar singly, according to the method already described. I then take two rectangular parallelopipedons of very soft iron, well polished, 6 inches in length, between 20 and 24 lines broad, and 10 or 12 lines thick‡: with these two parallelopipedons represented fig. 4. at N and S, I form the armor of my magnet by enveloping one extremity of each parallelopipedon with a stratum of my magnetic bars, so that the extremities of the parallelopipedons may project beyond the extremities of the bars 20 or 24 lines, and the other part may be enveloped by the ends of the set of bars. On this first layer of steel bars of 3 or 4 lines thick, I place a second which is three inches shorter than the first, so that the first projects beyond the second 18 lines on each side. The whole is secured at the ends by two binding pieces of copper, which press the bars close together, and prevent the armor from escaping.

Fig. 4. represents two artificial magnets composed according to the method just described. N and S are the extremities of the two iron parallelopipedons. The two other extremities are inclosed by the bars. Each magnet thus compounded is solidly connected

* By other experiments, the author has ascertained that the magnetism acquired by steel is least when it is either absolutely hard or annealed by a white heat, and greatest when it has been hardened and annealed by a very obscure red heat; from which middle term it diminishes either way, whether the bar be harder or softer. N.

† We have two sorts at least in the London market. The common sort is sold retail at 6d. or 7d. per lb. the finer, under the name of cast-steel (which I suppose it to be) is sold at one shilling per lb. and deserves its price. I have not been able to procure sheet steel thicker than 1-8th of an inch. N.

‡ All the weights and measures in this paper are French; but as extreme precision is no where implied, it was unnecessary to reduce them. N.

together by the copper pieces marked a, b, a′, b′. The pieces of contact A, R, join the opposite poles of the magnets.

Experience has shewn me, that with an apparatus of this form, each part weighing 15 or 20lb. a force of 80 or 100 pounds will be required to separate the pieces of contact; and that when an ordinary needle of the compass is placed on the two extremities of our two compound bars, fig. 4. they become magnetized to saturation without its being necessary to rub them with the upper pair of magnets. It is scarcely necessary to observe, that when magnets of greater force are desired, it is necessary, in proportion as the number of bars is increased, to augment their length also, and the dimensions of the parallelopipedons of iron which serve for the armor. It would be easy to ascertain the different dimensions which the magnets ought to have, in a manner sufficiently accurate for practice, from the laws of magnetism, and the position of the centre of action of the bars of steel, of different lengths and thickness, which we have explained in the course of this memoir.

VII.

On the Separation of Argillaceous Earth from Magnesia. By Mr. F. Accum.

To Mr. NICHOLSON.

SIR,

THE separation of argillaceous earth from magnesia, when both are combined in one substance, as is very often the case in mineral bodies, has been hitherto considered as one of the most difficult operations in the whole analysis of artificial and natural compounds. The experimental chemist, who is practically employed in the investigation of mineral substances, must be sensible of the difficulties which unavoidably accompany the present method of operation; and must likewise allow, that notwithstanding the utmost care, accuracy and skill, it is scarcely possible to avoid uncertainty in his conclusions and results. For these reasons, I beg leave to observe, that the above object may be accomplished to the utmost precision in the following manner: When both these earths are in a solution of muriatic acid in a perfectly saturated state, the argillaceous earth may be *totally* separated by means of carbonate of ammoniac; as this will only disengage that earth, and the magnesia will be retained in solution; which may then be separated by adding solution of pure potash or soda to the remaining fluid.

I am, Sir, your humble servant,

Haymarket, No. 17. FREDERICK ACCUM.

VIII.

Extracts from the Manuscripts of Leonard de Vinci. With Remarks, by J. B. VENTURI, Professor of Natural Philosophy at Modena, Member of the Institute of Bologna.*

I. ON the defcent of heavy bodies combined with the rotation of the earth, De Vinci fhows by a figure, that a body let fall from an eminence will continue perpendicularly over the fame fpot, notwithftanding the rotation of the earth, and confequently infers that it will defcribe a fpiral line. (It is an ellipfis.)

It was at the commencement of the 16th century that the works of Nicolas de Cufa were printed, in which that author endeavoured to renew the ancient doctrine of the motion of the earth, though in a confufed and metaphyfical method. The writing of de Vinci is nearly of the year 1510, and fhows that this notion was in a ftate of difcuffion in the minds of difcerning men before the time of Copernicus. It has been afferted, that Regiomontanus fupported this doctrine; but he oppofes it directly in a writing preferved by Schoner, and in his commentaries on the Almageft †. The doctrine of the motion of the earth was publicly maintained for the firft time at Rome, in 1533, by Widmanftat ‡, who affirmed that he had learned it from Copernicus. The work of this laft did not appear till 1543. Vinci was the only man at that time who was fufficiently acquainted with mechanics to apply the theory of combined motion to the fall of heavy bodies, an application of which the honour was affumed by Gaffendi in the laft century §. In this ftate the opinion of philofophers remained, until D'Alembert demonftrated, that heavy bodies projected towards the zenith ought not to fall exactly at the place whence they fet out. A fimilar idea has been taken up in my country. The tower Afinelli in Bologna is about three hundred feet high. A ball exactly round being let fall from this height to the earth, ought to deviate nearly fix lines from the perpendicular. J. B. Gullielmini made the experiment in 1792 with great care. He could not avoid fome aberrations, of which the mean refult, however, confirmed the truth of a fact which had before been demonftrated by aftronomy and mechanics ‖.

II. Concerning the earth divided into fragments.—L. de Vinci affirms, that if the earth were cut into fragments, and difperfed through the furrounding fpace, a fingle fragment being let fall would be carried to the common centre, which it would pafs to a nearly equal diftance on the oppofite fide, and return again nearly to the place whence it fet out; and in this way the vibrations would continue:—that if all the fragments were fuffered to fall at different times, they would meet, ftrike, and break each other, and a tumultuous

* From the "Effai fur les Ouvrages Phyfico-Mathématiques de Léonard de Vinci," of which notice is taken in Philof. Journal, I. 599. I have abridged the paffages in many inftances. All the remarks in the text are by Profeffor Venturi.

† Schoneri Opera, pars fecunda, cart. 127. Regiomontan. in Almageftum, l. p. conclus. 5.

‡ Marini Anchiatri Pontificii, tom. 2, pag. 351.

§ De motu impreffo a motore tranflato. Paris 1642.

‖ De diurno terræ motu experimentis confirmato. Bonon. 1792.—An experiment of this nature was propofed to the Royal Society, and a difcourfe read thereon by Robert Hooke, who inferred that the ball would in our latitude fall to the S. E. This, on trial about December 1679, proved to be the cafe. See Ward's Lives of the Grefham Profeffors, p. 184. N.

commotion

commotion would be produced in the atmoſphere, which would continue for years, until all the parts were united about the common centre *.

III. Concerning the earth and the moon.—That the earth is a ſtar; that the ſcintillation of the ſtars is an affection of the eye †; that the earth performs the ſame office of illumination to the moon, as the moon to the earth, but with contrary phaſes; that the earth in lunar eclipſes does not receive light by reflection from the moon, *nor the moon from the earth* in ſolar eclipſes; that the obſcure illumination of the dark part of the moon at the beginning of the firſt and end of the laſt quarters is produced by reflection of ſolar light from the earth.

IV. On the action of the ſun upon the ocean.—Our author affirms that the heat of the ſun cauſes the waters of the ſea to riſe in an eminence beneath the equator, from which they flow on all ſides, as may be obſerved in water heated over a fire; and that the aqueous eminence following the ſun in the diurnal motion is carried through about a thouſand miles per hour.

De Vinci has here applied the ſame principle to the waters of the ocean, as Halley has ſince uſed to explain the trade winds in the atmoſphere ‡.

V. The ancient ſtate of the earth.—When the water of rivers depoſited its mud upon the marine animals living near the ſhore, this mud impreſſed itſelf upon the animals themſelves. When the ſea afterwards retired, this mud became petrified all round, and within the ſhells of teſtacea which it had penetrated. Theſe are found in various places; and moſt of the ſhell-fiſh petrified in the mountains have their ſhells entire, particularly thoſe of the greateſt age and hardneſs. In anſwer to a ſuppoſed objection, that the influence of the ſtars may have formed theſe ſhells in the mountains, the author requires to be ſhewn any place where this operation of the ſtars is in actual progreſs to form ſhells of different ages and ſpecies in the ſame place. And how upon that ſyſtem it can be explained why the gravel has become indurated in ſtrata at different heights in the mountains. This gravel, continues he, has been tranſported thither from various places by the currents of rivers. It was formed of fragments of ſtone, of which the corners have been worn down by the frictions, blows, and falls they have undergone in the water which rolled them to their preſent ſituation. And how can this ſyſtem explain the great number of different kinds of leaves bedded in ſtone near the tops of mountains? and the Alga, a marine plant, intermixed with ſhells and ſand, and petrified in a maſs with ſea crabs broken and confounded with the ſame ſhells.

* In this ſection it is evident, as Profeſſor Venturi remarks, that our author has a clear comprehenſion of the inertia of matter. Another ſtep in the proceſs of reaſoning would have given a revolution, to his falling fragment, in an appropriate orbit. The vibration of a body in a cavity through the centre of the earth to the antipodes, and the retention of the moon in its orbit by the combination of the projectile and gravitating forces are ſtated in a paſſage of ſome length by Plutarch, in his treatiſe *De placitis philoſophorum*, as I well remember, but have not the work at hand to quote. N.

† On this ſubject it may be remarked in favour of ſcintillation being a conſequence of the irregular denſity of the air, and not an affection of the eye, 1. That it is leſs on lofty mountains, and countries where the air is almoſt conſtantly ſerene. 2. That in the ſame ſtar it is leſs, the greater the altitude. And 3. That, contrary to a general obſervation, it may be obſerved through a teleſcope, provided the diſc of the ſtar be enlarged by deranging the focal adjuſtment. N.

‡ And very lately again applied to the ſea by Count Rumford. Philoſ. Journal, I. 573. N.

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The ſea changes the equilibrium of the earth. The oyſters and other ſhells which are formed in the mud of the ſea, atteſt the change which the earth has undergone about the centre of the elements. Large rivers always wear away the earth which they detach by friction from their beds. This corroſion diſcovers to us many banks of ſhells heaped together in different layers, and the ſhell-fiſh have lived in the ſame place when the waters of the ſea covered them. Theſe banks in the courſe of time have been covered by other ſtrata of mud of different thickneſſes; ſo that the ſhells have been bedded in the mud heaped above them in ſuch a manner as to riſe above the ſurface of the water. At the preſent time theſe beds are at the height of hills and mountains, and the rivers, by wearing them away, diſcover the ſtrata of ſhells at their ſummits. Here then is a portion of the earth become lighter, which continually riſes while the oppoſite parts approach nearer and nearer to the centre of the earth; and that which was formerly the bottom of the ſea is now become the ſummits of the mountains.

When a river forms banks of mud or ſand, and afterwards quits them, the water that runs from theſe maſſes ſhews the manner in which the mountains and valleys may by degrees be formed in a ſoil riſing from the bottom of the ſea, though this ground might at firſt have been nearly plain and uniform. The water which flows from this land elevated from the bottom of the ocean, begins to form currents at the lower parts, and excavates the beds of rivulets which receive the fluid from the neighbouring parts. The rivulets, afterwards fed by the rain waters, become broader and deeper every day, and are converted into torrents paſſing through ravines: they unite into rivers, and by continually wearing away their banks they convert the land between them into mountains. The rains have inceſſantly ſwept and degraded theſe mountains. The elevated rock remains ſurrounded by the air; the earth of the ſummit and its ſides has deſcended to its baſe, and, by raiſing the bottom of the ſea which ſurrounded that baſe itſelf, has forced it to retire to a diſtance.

Vinci is here the firſt among modern philoſophers who maintained that the greateſt part of the continents have formerly exiſted at the bottom of the ſea. We cannot reject this doctrine, which is proved by every geological obſervation; but we do not yet diſcern the means of reconciling the ſucceſſive tranſportation of the ſea, on the ſurface of the globe, with the laws of gravitation. L. de Vinci offers an explanation which may well deſerve ſome examination. It is different from the opinion of Bernier, who has aſcribed a motion to the centre of gravity, without changing the arrangement of the ſolid parts of the earth. But the profound geometer, who has lately traced the ſyſtem of the world, agrees that the obſervations of Bouguer and Maſkelyne on the attraction of mountains do not entirely determine the denſity of the interior part of the earth *. We may therefore ſtill ſuppoſe at preſent, as Vinci does in his writings, that the fluid maſs in our globe is equal, or may be even greater than the ſolid portion: or, if this hypotheſis be not admitted, it will be ſufficient if we ſuppoſe that there are ſeveral detached ſolid maſſes in our globe, ſo that each continent may be conſidered as a ſmall part of the total maſs of the earth. Whence the maſs of matter tranſported by the rain during the lapſe of centuries from the ſummits of mountains to the bottom of the ſea, may be ſufficiently great, in proportion to the maſs of each continent, to cauſe thoſe continents to emerge more and more above the ſurface, or

* Expoſition du Syſtême du Monde, par P. S. La Place.

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to cause them to rise on one side, while they become immersed on the other, until at length some great shock may reverse them entirely, or cause some new masses to rise from the bottom of the sea. This will be, it may be said, an hypothetical notion; but it is a notion which shews that de Vinci contemplated the cause of the phenomenon in a way sufficiently agreeable to the mechanism of gravitation. No philosopher since his time has yet thought of a more satisfactory explanation *.

VI. Concerning flame and air.—Where flame is produced, a current of air takes place around, which is necessary to preserve and augment the flame. The stronger the motion of the air, the more brilliant the flame and the greater the heat. Fire incessantly destroys the air which nourishes it; and it would produce a vacuum, if other air did not rush in and fill it. When the air is not in a state proper to receive the flame, neither flame nor any terrestrial or aërial animal can live. No animal can live in a place where flame cannot live.

Smoke is produced in the centre of the flame of a candle, because the air which enters into the composition of the flame cannot penetrate to its interior part. It is arrested at the surface of the flame, which it condenses; by becoming the aliment of the flame it is transformed into it, and leaves a void space, which is successively filled by other air.

* I must confess that the difficulties of this theory do not appear to be removed either by the observations of the author or his learned commentator. I apprehend that the hypothesis requires or asserts, that some natural process should take place to raise the land above the surface of the water, which was originally beneath that surface; and the assumed principle is, that it shall rise because lighter than an equal mass of water. The specific gravities of mineral substances are totally repugnant to this notion of floating continents, unless we suppose them to be hollow, which is by no means rendered probable to the required degree. Neither do we know of any facts which shew that the longitudes and latitudes of places on the several continents are liable to change, as must be the case if each continent were a separate mass capable of librating on a comparatively narrow face of support, as seems to be implied in one part of Professor Venturi's annotation. It appears however to be well ascertained, that the sea has formerly surmounted the level of high, and perhaps the highest mountains; and from the regularity of disposition which in many instances is observable (Philos. Journal, I. 221.) it may be doubted whether the shock of a comet (Philos. Journal, II. 42.) and the supposed change of the earth's axis of rotation are sufficient to account for its subsequent depression. I think it is scarcely disputable, that the whole of the solid mass of the earth is connected together, and that the fluid portion occupies the cavities to which it can have access in this solid. If we suppose the globe of the earth to have been formerly enveloped by a sea, whose surface was between two and three miles higher than the surface of the present ocean, or even much less elevated, the simple enquiry will be, what has become of it? It cannot have assumed the elastic state; for we know the medium weight of the atmosphere, which corresponds with little more than a shell of water covering the earth to the depth of about thirty-three feet. We are therefore led to the following objects of investigation: 1. Is the earth solid throughout, or does it afford natural cavities into which the water may, in the course of ages, have found its way? 2. As a very large part of the present surface of the earth has been thrown up by the chemical process of volcanic combustion, and these processes must have left cavities beneath the surface, it may become a matter of computation to determine the solid contents of volcanic product above the present level of the sea, in order to ascertain the quantity of depression the sea would have suffered on the supposition of its having sooner or later flowed into those cavities. 3. If, upon careful enquiry into these facts, it should be ascertained, or rendered highly probable, that the primitive sea has in a great measure disappeared by flowing into cavities in the solid mass of the earth, would not the globe of the moon afford an instance in confirmation of such a process? For the obscure parts of that globe which were at first thought to be seas are observed to be cavities, probably the beds of ancient seas. It seems likely that the component parts of the moon (whatever may be those of the other planets) are nearly the same as of the earth. Yet its atmosphere as well as its surface indicates a great want, if not the total absence of water. Has it required less time for the lunar sea to be absorbed?—Much more might be said: but on an object where facts are wanting, and conjectures plentiful, too much has perhaps been said already. N.

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Muſchenbroek and moſt of the philoſophers of the preſent century have attributed ſcarcely any other function to the air than that of compreſſing the caloric or fuel in a ſtate of combuſtion, and blowing away the aſhes. Chemiſtry has lately proved what Vinci had before diſcerned, and Mayow and Hooke had ſuſpected towards the end of the laſt century.

VII. and VIII. On Statics.—The author explains the theory of the oblique lever, the inclined plane, and the general principle of virtual velocities in machines.

Vinci and Galileo both obſerved, that the deſcent of heavy bodies is made more ſpeedily through an arc of a circle than by an inclined plane; but their proofs are imperfect in certain reſpects. It has ſince been demonſtrated that the cycloid is the curve of quickeſt deſcent. Neverthelefs, I find that there is a minimum of time of deſcent in a circular arc, which may be determined in a ſynthetical method of conſiderable ſimplicity, by means of the following theorem.

An arc of a circle which does not exceed 60° is a curve of ſpeedier deſcent than any other curve which can be drawn within the ſame arc:—and the arc of 90° is a curve of ſpeedier deſcent than any other curve which can be drawn without the ſame arc*.

IX. Concerning water drawn from a canal.—The quantity of water which iſſues from a canal through a given aperture, may vary from many cauſes. 1. From the greater or leſs height of the water of the canal above the aperture. 2. From the greater or leſs ſwiftneſs of the water along the ſide or bank, in which the opening is made. 3. From the greater or leſs convergence of the ſides of the aperture. 4. The greater or leſs thickneſs of the ſide of the canal. 5. Whether the aperture be circular, ſquare, triangular, or oblong. 6. Becauſe the aperture is more or leſs obliquely ſituated with regard to the bearing or direction of the ſide. 7. Or more or leſs inclined to the horizon. 8. Whether the opening be in a convex or concave part of the bank. 9. Whether there be cavities or prominences in the bed of the canal oppoſite the aperture. 10. Whether the air do or do not inſinuate itſelf into the current of water which iſſues forth. 11. Whether the water at its emiſſion fall freely in the air, or is conducted away by an open trough, or by a pipe cloſed all round. 12. Whether this conducting pipe have a greater or leſs diameter with regard to the quantity of water which deſcends in the tube itſelf. 13. Whether the ſame conducting pipe have a greater or leſs length in its deſcent. And 14. Whether the bore of this pipe be equal or rough, ſtraight or curved.

It muſt be admitted here, as well as elſewhere, that De Vinci, though poſſeſſed of a mind ſo powerful as to diſcern the true cauſes of natural phenomena, had not the advantage of modern analyſis to aſcertain and demonſtrate the quantum of action of theſe cauſes. But, on the other hand, it muſt be allowed that hydraulics even in our time has not yet perfectly and accurately determined all the laws according to which the fourteen circumſtances pointed out by Leonardo affect the quantity of water emitted through an aperture of a given magnitude.

X. Concerning circular eddies, or whirls of water.—The author marks the effect of the inertia of bodies which produces a centrifugal force in curve-lined motions. He remarks that the cavity produced in water by a whirling motion is leaſt at the bottom, becauſe there the

* For the demonſtration I muſt refer to the Eſſay, p. 19. N.

preſſure is greateſt; and that, contrary to the obſervable motion in a wheel, the parts neareſt the axis in the preſent caſe move the ſwifteſt *.

XI. On viſion.—The inverſion of images formed in the darkened chamber by rays admitted through a ſmall hole in a plate of metal are explained by a diagram, and applied to the phenomena of viſion. It is alſo remarked, that the apparent magnitude of remote objects may be enlarged by rendering the pencils of light more convergent. This is ſhewn by a figure, but the means are not perſpicuouſly explained.

XII. On military architecture.—Under this title the author gives directions for conſtructing military works; and conſiders their relative properties with regard to attack and defence. He exhibits, as his commentator remarks, a ſketch nearly complete of the art of fortification, and the attack and defence of places, at the commencement of the ſixteenth century. We obſerve platforms, buttreſſes or counterforts, ravelins, the glacis ſurrounding the ditch, trenches, advantages of the ricochet, mines and countermines, and in ſome deſigns of de Vinci there are even counterguards. It muſt however be remarked, that Leonardo was much ſuperior to the engineers of his time; in proof of which his obſervations in this ſection may be compared with what Machiavel delivers on the ſame ſubject in his Art of War, and what Albert Durer has written upon fortification †.

It is pretended that the baſtions of Verona ‡ were the firſt which were conſtructed with right-lined faces, flanked in the modern faſhion; and the merit of this invention has been aſcribed to San Michel. The baſtions of Verona were however conſtructed after the death of Leonardo, who had explained the neceſſity of that diſpoſition, and has marked embraſures in each flank of the baſtion in one of his figures.

Geuſs, in his *Théorie de l'Art du Mineur* ||, reproaches Vallière for having robbed Peter Navarro of the glory of the invention of mines, to attribute it without foundation to Francis Georgi §. Vallière may be defended by the teſtimony of Biringuccio, who was the countryman and contemporary of Georgi. He expreſsly ſays ¶, "that it was this engineer who, being conſulted by Navarro reſpecting the means of taking the caſtle of Naples, propoſed and executed the mines, and that the glory remained with the commander General Navarro, becauſe renown diſpoſes itſelf on the ſide of great men." But, in fact, the invention of mines with gun-powder is more ancient than either of theſe perſonages. The Genoeſe executed them in 1487 **. The manuſcript N° 7239 of the French National Library was written by an Italian who lived at the commencement of the 15th century. The author explains very clearly (fol. 32) the manner of taking a caſtle ſituated on a mountain, by the operation of mines ††.

XIII. Concerning certain inſtruments.—1. The proportional compaſſes. Its centre is moveable; and, as the author remarks, it may be uſed for the proportions of incommenſurable quantities, and alſo to form an oval which ſhall have a given ratio to a given circle.

* Profeſſor Venturi has treated this ſubject in his Recherches Expérimentales, &c. p. 58, for an account of which work ſee our Journal, I. 525.

† De urbibus arcibus caſtellis, fol. Paris, 1535.

‡ Maffei Iſtoria di Verona, part. 3, cap. 4.

|| In 8vo. Maſtricht 1778. § 21.

§ Folard, tom. iii.

¶ Pyrotechnia, liv. 10. cap. 4.

** Guicciardini Iſtoria, lib. vi.

†† Mr. Venturi gives a more particular account of this manuſcript and its contents in the notices at the end of the preſent treatiſe.

circle. M. Venturi informs us, that from a drawing in the manuſcript it does not appear to have been different from the inſtrument now in uſe. 2. An inſtrument to ſhew the conſtitution and denſity of the air, and when the weather inclines to rain. From the figure it appears to have been a balance loaded at each end, and provided with a graduated circle to ſhew its changes of inclination. M. Venturi thinks that one of the weights in equilibrio was a body proper to become charged with the humidity of the atmoſphere. This does not very well agree with the conſideration of denſity, though it muſt be confeſſed that the equal magnitudes of the two weights in the drawing do not give much countenance to the notion of its having been a ſtatical baroſcope. 3. A leathern caſe or clothing for a diver in the pearl fiſhery. 4. A piece (*bâton*) which locks alternately in the teeth of a crown wheel to operate like the verge of the balance in clocks; but for what purpoſe is not ſaid *.

XIV. Two chemical proceſſes.—1. A flaming ball compoſed in the following manner:—Take the charcoal of willow, nitre, brandy, reſin, ſulphur, pitch, and camphor. Mix the whole together over the fire. Plunge a woollen cord in the mixture, and form it into balls, which may afterwards be provided with ſpikes. Theſe balls being ſet on fire, are thrown into the enemy's veſſels. It is called the Greek fire, and is a ſingular compoſition, for it burns even upon the water. Callinicus the architect taught this compoſition to the Romans (of Conſtantinople), who derived great advantage from it, particularly under the emperor Leo, when the Orientals attacked Conſtantinople. A great number of their veſſels were burned by means of this compoſition.

2. Oil fit for painting. Chooſe the moſt perfect nuts, take off the ſhell, ſoak them in a veſſel of water to ſeparate the ſkin; then leave the kernels in clear water, which is to be changed as often as it becomes turbid, which may be ſix or eight times. After a certain time, the nuts on being ſtirred will be found to mix with the water, and form a ſolution reſembling milk. Expoſe this in plates to the open air, and the oil will riſe to the ſurface. In order to obtain this oil very clean and pure, provide cotton wicks, one end of which is to be dipped in the oil, while the other part paſſes over the border of the veſſel, and deſcends into the neck of a glaſs phial two inches below the ſurface of the liquor in the plate. The oil will by degrees filtrate along the wick, and paſs very fine into the phial, all the impurities remaining in the plate. All the oils of grain and of nuts are equally clear. It is the manner of extracting them which renders them foul.

The compoſition of the Greek fire here given by Vinci, is found nearly in the ſame words in Baptiſta Porta†, whence it appears that both authors derived their information from the ſame ſource. The modern diſcoveries in chemiſtry reſpecting combuſtion have diſcloſed the whole ſecret of compoſitions which burn without acceſs to the atmoſphere, but by means of oxygene afforded from nitre. The balls deſcribed by Frezier ‡, which ſhine on the ſurface of water, are nothing elſe but the Greek fire.

XV. Concerning method.—It is always of advantage to the underſtanding to acquire

* The intereſting commentary or note on this laſt paſſage has already been given, for the moſt part, at page 51 of the preſent number.

† Mag. Natur. lib. xii. cap. 2.

‡ Des feux d'artifices, edit. de 1747, p. 355. See alſo p. 332.

knowledge

knowledge whatever may be its nature; we may afterwards choose the good, and reject the useless. (Qu.?)

Theory is the General; Practice is the Army.

Experiment is the interpreter of the contrivances of nature. This interpreter never deceives us. Our judgment sometimes misleads itself in expectation of consequences which experiment refuses to verify.—We must recur to experiment, and vary the circumstances until we have deduced general rules, for it is experience which affords the true rules.—But you may ask, What is the advantage of these rules? I reply, that they direct our researches into nature, and the operations of art. They prevent us from deceiving ourselves or others by the promise of results which cannot be obtained.

There is no certainty in sciences to which some part of the mathematics cannot be applied, or which do not depend in some manner upon mathematical knowledge.

In the study of sciences which depend on the mathematics, those who do not consult nature, but authors, are not the children of nature. I would call them her grand-children. Nature, in fact, is the sole leader of true genius. But such is the folly of men. He who chooses rather to learn from the original source, instead of applying to authors, becomes an object of derision for his singularity *.

IX.

Observations and Experiments on the Formation of Sulphate of Soda, or Glauber's Salt, in Salt Waters, at a Temperature beneath the Freezing Point of Water, and upon an easy Method of disengaging all the deliquescent Salts. By M. Gren †.

THE influence of temperature upon the established laws of mutual decomposition of the neutral and middle salts, is a circumstance very essential to be observed. Many salts are not decomposed above the temperature of freezing water, though very well beneath that temperature. Such, for example, are the sulphate of alumine and the muriate of soda; the sulphate of magnesia and the same muriate.

The formation of Glauber's salt during congelation in salt water, wherein previous analysis did not discover it, had long since engaged the attention of the author. He concluded that the sulphate of soda owed its origin to the mutual decomposition of sulphate of lime and muriate of soda, at a temperature below zero. A more accurate analysis of these waters after the severe cold of 1794 and 1795, proved that he was mistaken, and that the sulphate of soda had been formed by the double decomposition of the muriate of soda and the sulphate of magnesia. The excessive cold of 1785 had already exhibited this decomposition to Scheele, and he had shown that sulphate of soda was produced from a mixture of two parts of the solution of sulphate of magnesia, and one part of the muriate of soda, exposed to the temperature of ice.

* Professor Venturi intends to publish as speedily as circumstances will permit, in three complete treatises, the whole works of De Vinci on mechanics, hydraulics, and optics. N.

† The memoir of M. Gren was addressed by himself in manuscript to the Council of Mines in France, who published it in the xxviith Number of the Journal des Mines. Citizen Descotils abridged the same in the xxivth volume of the Annales de Chimie, page 121. The above paper is a translation from his abridgment. N.

M. Gren was convinced by experiment, that the ſulphate of magneſia in ſalt waters forms at a ſufficient degree of cold all the ſulphate of ſoda which can then be afforded, and of which they did not before contain the ſmalleſt particle. He endeavoured, but conſtantly without ſucceſs, to reproduce the muriate of ſoda, and the ſulphate of magneſia, by an elevation of temperature. So that ſalt waters which contain ſulphate of magneſia change their nature; and their compoſition is no longer the ſame when they have been ſubjected to ſome degrees of cold below the freezing point; and a ſubſequent increaſe of heat will not reſtore their former ſtate.

The quantity of muriate of magneſia in ſalt waters which contain ſulphate of magneſia, is increaſed by a temperature beneath zero. It is therefore productive of a real loſs to ſuffer the ſalt water to remain in the baſons during the winter, becauſe they will afterwards afford a muriate of ſoda of a bad quality, and the ſulphate of ſoda which is obtained will not compenſate for this diſadvantage. It appears likewiſe that the hope of concentrating ſea water by froſt is chimerical.

It was an important queſtion to be reſolved in the art of making ſalt, what might be the means of ſeparating the deliqueſcent ſalts even before the evaporation. In this reſpect M. Gren has ſucceeded. His proceſſes are founded on the decompoſition, well known to chemiſts, of muriate of lime by ſulphate of ſoda, and muriate of magneſia by cauſtic lime.

If the water contain only muriate of lime with the muriate of ſoda, the ſulphate of ſoda is ſufficient: if there remain muriate of magneſia and ſulphate of ſoda, lime will ſuffice. In this caſe muriate of lime is formed, which afterwards decompoſes the ſulphate of ſoda by double affinity.

If the water contain the muriate and ſulphate of magneſia without ſulphate of ſoda, it will be neceſſary to employ lime and ſulphate of ſoda at the ſame time.

The ſame ſubſtances muſt alſo be employed, if the water contain the muriates of lime and magneſia together; which then entirely exclude the ſulphates of ſoda and of magneſia.

Laſtly, if the ſulphate and the muriate of magneſia be preſent with the ſulphate of ſoda, lime only need be employed, unleſs the quantity of the ſulphate of ſoda be found inſufficient. In this caſe a portion of the ſalt muſt be added.

Theſe proceſſes introduce no foreign ſalt into the waters, becauſe they are already ſaturated with ſulphate of lime, which does not render the muriate of ſoda more impure, becauſe it ſeparates in the ſtate of ſchlot. They have the advantage to clear it of the ſulphates of ſoda and magneſia, which alter the purity of the muriate of ſoda, and render it bitter. Beſides which, in the practice, no mother water remains. The whole of the fluid may be evaporated to the laſt drop, and all the ſalt extracted, which will conſtantly be pure marine ſalt. The directors of ſalt works will eaſily perceive how much profit will thus be obtained with regard to time and fuel conſumed in the evaporation and drying of the ſalts. But this is merely a ſecondary profit, greatly inferior to the principal advantage of obtaining a pure ſalt not deliqueſcent, but capable of reſiſting the impreſſion of the air, and of being preſerved and tranſported without loſs.

The ſtrongeſt objection againſt the uſe of theſe proceſſes may ariſe from the neceſſity of purchaſing ſulphate of ſoda; and this objection would be very well founded, if the ſalt waters were not for the moſt part of ſuch a nature as to afford it themſelves at a ſmall expence; that is to ſay, by their maceration at a temperature below zero. It would be ſufficient

cient to leave a certain quantity in the basons exposed to the cold during the winter. It would not indeed be proper to extract the common salt from these waters, after having separated the sulphate of soda, because they would then contain too great a quantity of muriate of magnesia. It would be more advantageous to add sulphate of iron to prepare the sulphates of soda and of magnesia.

With regard to such waters as do not contain any sulphate of magnesia, which is very rare, it would still be of advantage to purify them by these means; because the water must be very bad, and highly charged with deliquescent salts, to require more than fifty or seventy-five pounds of sulphate of soda for thirty quintals of salt obtained by evaporation.

In order to make use of this method, it is proper to be well acquainted with the principles which enter into the composition of the water intended to be purified. It then will be known whether lime alone, or sulphate of soda, or both substances together, ought to be used. Immediate experiment must afterwards determine what quantity ought to be used to insure the most perfect success.

X.

A Report made to the Council of Trade and Mines in Spain, on a new Kind of Wood for Dyeing, named Paraguatan. By D. DOMINIQUE GARCIA FERNANDEZ, Inspector of Coinage.*

IN compliance with the order of the Supreme Council of Commerce and Mines I have undertaken a chemical examination of the wood known at Guiana by the name of Paraguatan; which I have carried as far as appeared necessary to ascertain the nature of the wood, and the advantages to be derived from it. In the first place I observed that the bark, the wood properly so called, and the leaves of paraguatan afford different colours. The leaves do not deserve notice, because they produce only a false and disagreeable colour. My researches were chiefly directed to the bark, which is the part most deserving of attention. But my remarks upon the bark may also be extended to the wood; for, though this affords a different colour, it presents nearly the same phenomena as the bark itself.

When the bark is boiled in water it affords a coloured extract, which, when exposed to the action of the sulphuric, muriatic or nitric acid, resists their agency for a longer time than brazil or logwood does. The colour may be revived by means of alkalis, after it has been destroyed by combination with acids.

Vinegar, lemon juice and tartar render this colour more brilliant. They give it a fine rose colour; whereas these acids entirely destroy the colours of brazil and logwood.

The fecula of the bark of paraguatan fixes and attaches itself to wool, cotton, and silk. The colour is brighter on silk than on wool, and brighter on wool than on cotton.

The same fecula dried is afterwards soluble in alcohol. It communicates to it a tinge similar to that afforded by cochenille.

By mixing alum with a very concentrated decoction of the same substance, a kind of lac

* Translated from the Spanish by Cit. Venturi, Annales de Chimie, XXIII. 340.

lac is obtained, which is neither ſo bright nor ſo beautiful as is obtained from cochenille by the ſame proceſs.

The ſame decoction mixed with nut galls afforded me a precipitate of a faint roſe colour. The infuſions of brazil wood and logwood mixed with the infuſion of galls aſſume a deeper and browner colour. Ours, on the contrary, becomes brighter, and aſſumes a pale tinge of the roſe, or ſome other ſimilar and delicate colour.

It muſt be confeſſed that the colour obtained from paraguatan has not the force of that of cochenille. But it is ſuperior to thoſe of madder, brazil wood, and logwood. For it reſiſts vinegar, lemon juice, and tartar. Soap itſelf does not deſtroy it ſo quickly as it does thoſe of brazil and logwood.

Our bark likewiſe affords the advantage, that, by employing it in certain doſes, and giving a due preparation to ſilk, we may obtain various ſhades of roſe and poppy colour, which cannot be had by means of carthamus but by difficult proceſſes, long waſhings, alkaline mixtures, and other embarraſſing manipulations.

By examination of the external appearance of a piece of the wood of paraguatan, it appears to me to be the ſame tree which Francis Correal * ſays he obſerved in the province of Popayan, not far from Guiana. The ſame author relates, that this tree is different from that of brazil; that the trunk is of the thickneſs of a man's thigh; that its bark is filled with longitudinal indentations; that the wood and bark are of a fine red; and that the Indians uſe this wood mixed with a red earth to dye their cotton garments.

The colour obtained from paraguatan does not reſiſt the action of light. No colour can withſtand this teſt. It is enough that our colour withſtands it longer than thoſe of brazil and logwood. I muſt not conceal, that theſe two trees afford the colouring matter in greater abundance than the paraguatan.

From theſe facts I conſider the paraguatan as one of the moſt valuable productions which America furniſhes to Spain. It may be advantageouſly employed in the art of dyeing throughout Europe. It is to be wiſhed that enquiry might be made at Popayan, in order that the earth and the wood mentioned by Correal might be procured. It is alſo deſirable that the governor of Guiana ſhould collect all the information which can be procured reſpecting the paraguatan, and tranſmit the ſame to us with other ſamples of the wood, the leaves and the flowers of this tree, to enable us to determine its ſpecies.

The knowledge of this wood begins to be extended. For I have lately received a portion of its bark, and a red matter which an Engliſhman, named *Milnes*, has obtained from Guiana. It is to be preſumed that this matter is the ſame as is mentioned by Francis Correal in his travels.

SCIENTIFIC NEWS.

THE adminiſtration of finances and contributions of the French Republic in Italy, having at its diſpoſal a great number of the moſt valuable pieces of ſculpture, painting, and marbles†, ariſing from confiſcations made of (the property of) the enemies of the French Republic,

* Voyage aux Indes Occidentales, p. 420, of the French tranſlation printed in 1722.

† *Marbres*, which I underſtand to denote tablets, ſtatues, bas-reliefs, and every other work formed of marble. N.

Republic, being defirous of fpeedily difpofing of all thefe mafter-pieces of art, has charged citizen Hubert (who is) attached to the adminiftration of finances in quality of artift, to offer them for fale to individuals, or focieties. The lovers of the arts, academies of painting, fculpture, and the fciences, will have a matchlefs opportunity of acquiring the treafures of art, of which catalogues are in the hands of the whole world, and defcriptions in all the publications of travels through Italy.

It will therefore fuffice to offer for fale the marbles of the famous Villa Albani, the galleries of the Princes Albani, Brafchi, and other monuments, of which a catalogue will be given, with eftimates of price made by artifts, upon which a confiderable abatement will be allowed. Bills (payable) in gold or filver on neutral countries, fuch as Florence, Venice, Vienna, and even Switzerland, will be accepted. Purchafers belonging to nations at war with France will have paffports for tranfporting whatever they may purchafe, whether by land or by fea, and for embarking the fame at the ports of Rome and Civita Vecchia. The agents belonging to the fame inimical powers may, on their approach to Italy, procure all the neceffary paffports to come with all fecurity to treat and choofe themfelves the objects which may fuit their wifhes, by addreffing Citizen Hubert, rue de la Croce, at Rome. Speed and ready money are the beft means to be ufed in this bufinefs. Feb. 28th, 1798.

The foregoing advertifement was fent by the therein mentioned Hubert to Mr. Trevor, the Britifh Minifter at Turin, and by him tranfmitted to Sir Richard Worfley in London, where it arrived on the 27th of March. I obtained it of the Right Hon. Sir Jofeph Banks, Bart. It is unneceffary for me to make any comment, either political or otherwife, on its contents.

Account of the Society of Civil Engineers. [Concluded from p. 48.]

THE fame period gave rife alfo to an affociation of fome gentlemen employed as abovementioned. They often met accidentally, prior to that union, in the houfes of parliament and in courts of juftice, each maintaining the propriety of his own defigns, without knowing much of each other. It was however propofed by one gentleman to Mr. Smeaton, that fuch a ftate of the profeffion, then crude and in its infancy, was improper ; and that it would be well if fome fort of occafional meeting in a friendly way was to be held, where they might fhake hands together and be perfonally known to one another. That thus the fharp edges of their minds might be rubbed off, as it were, by a clofer communication of ideas, no ways naturally hoftile; and might promote the true end of the public bufinefs upon which they fhould happen to meet in the courfe of their employment, without joftling one another with rudenefs too common in the unworthy part of the advocates of the law, whofe intereft it might be to pufh them on perhaps too far in difcuffing points in conteft.

Mr. Smeaton immediately perceived the utility of the idea, and at once embraced it. In March 1771, a fmall meeting was firft eftablifhed on Friday evenings, after the labours of the day were over, at the Queen's Head tavern, Holborn. And from a few members at firft, it foon increafed, fo that in the fpace of twenty years they amounted to fixty-five and upwards. But of thefe there were only about fifteen who were real engineers employed in public works, or private undertakings of great magnitude.

Among thefe we find the names of Yeoman, Smeaton, Grundy, Milne, Nickalls, Jeffop, Golborne, Whitworth, Edwards, Jofeph Prieftley, Major Watfon, Boulton, Whitehurft, Rennie, Watt, and fome others. The other members were either amateurs, or ingenious workmen and artificers connected with and employed in works of engineering.

This

This aſſociation declared itſelf a ſociety, and a regiſter was kept of the names and numbers of its members. Converſation, argument, and a ſocial communication of ideas and knowledge in the particular walks of each member, were at the ſame time the amuſement and the buſineſs of the meetings.

In this manner, ſometimes well attended, and at other times not ſo, as the members were diſperſed all over England, the ſociety proceeded until May 1792, when it ceaſed to exiſt by mutual conſent of the principal members.

Some untoward circumſtances in the behaviour of one gentleman towards Mr. Smeaton, gave riſe to the diſunion. No one was ever more obliged than that gentleman (who is now deceaſed) to Mr. Smeaton for promoting him in buſineſs, and many eſſential offices in life. The offence given was done away by an apology at the deſire of the company, and by the good-nature of Mr. Smeaton; but the remembrance of it had an effect on all preſent.

Afterwards it was conceived and intended to renew this ſociety in a better and more reſpectable form. Steps were taken for that purpoſe, and Mr. Smeaton agreed to be a member. But before the firſt meeting could be held, he was no more. He died the 28th of October 1792, and their firſt meeting was in April 1793.

It was conceived it would be a better plan that the members ſhould dine together at a late hour after attendance in parliament, and paſs the evening in that ſpecies of converſation which provokes the communication of knowledge more readily and rapidly than it can be obtained from private ſtudy or books alone.

The firſt meeting of this new inſtitution, *The Society of Civil Engineers*, was held on the 15th of April 1793, by Mr. Jeſſop, Mr. Mylne, Mr. Rennie, and Mr. Whitworth.

The conſtitution was agreed on, and afterwards acceded to by all. That there ſhould be three claſſes in the ſociety. The firſt claſs as ordinary members, to conſiſt of real engineers, actually employed as ſuch in public or in private ſervice. The ſecond claſs as honorary members, to conſiſt of men of ſcience, and gentlemen of rank and fortune, who had applied their minds to ſubjects of civil engineering, and who might, for talents and knowledge, have been real engineers, if it had been *their good fortune* to have it in their power to employ others in this profeſſion: and alſo of thoſe who are employed in other public ſervice, where ſuch and ſimilar kinds of knowledge are neceſſary. And the third claſs as honorary members alſo, to conſiſt of various artiſts, whoſe profeſſions and employments are neceſſary and uſeful to, as well as connected with, civil engineering.

The meetings are held at the Crown and Anchor in the Strand, every other Friday during the ſeſſion of parliament. And the liſt of members are: Of the

Firſt claſs. Ordinary members. William Jeſſop, Robert Whitworth, John Rennie, F.R.S. Ed. Robert Mylne, F.R.S. James Watt, F.R.S.—L. and Ed. James Golborne, Sir Thomas H. Page, Knt. F.R.S. John Duncombe, Captain Joſeph Huddart, F.R.S. Henry Eaſtburne, William Chapman, M.R.I.A. James Cockſhutt.

Second claſs. The Right Hon. Sir Joſeph Banks, Bart. P.R.S. Knight of the Order of the Bath, &c. Sir George A. Shuckburgh Evelyn, Bart. F.R.S. General Bentham, Joſeph Prieſtley, Eſq. Doctor Charles Hutton, F.R.S. Henry Oxendon, Eſq. The Right Hon. the Earl of Morton, F.R.S. John Lloydd, Eſq. F.R.S. Rt. Hon. Ch. Greville, Eſq. F.R.S.

Third claſs. William Faden, geographer; Jeſſe Ramſden, F.R.S. inſtrument-maker, &c. John Troughton, inſtrument-maker, &c. John Foulds, mill-wright, &c. Samuel Phillips, engine-maker; Samuel Brooke, printer; John Watté, land-ſurveyor, &c.

Escapements.

Philos. Journal Vol. II. Pl. III. facing p. 96.

Fig. 1. Crown Wheel

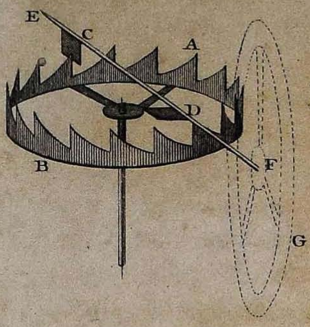


Fig. 2

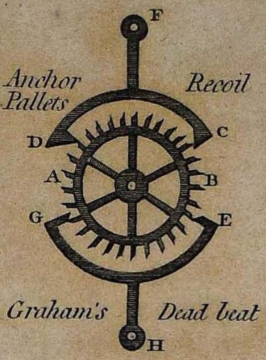


Fig. 3. Free or detached

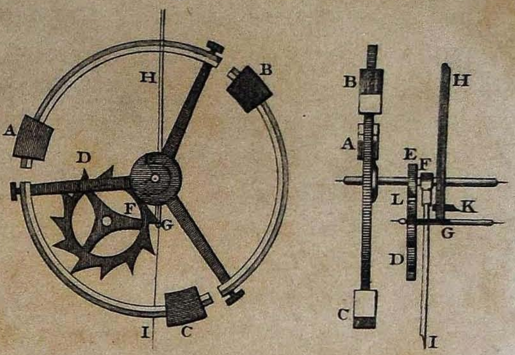


Fig. 4.

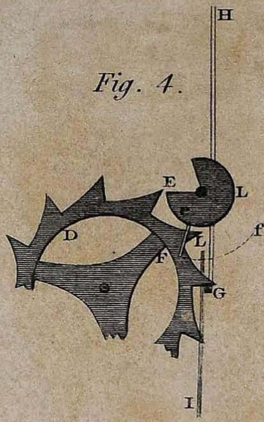


Fig. 5. Horizontal

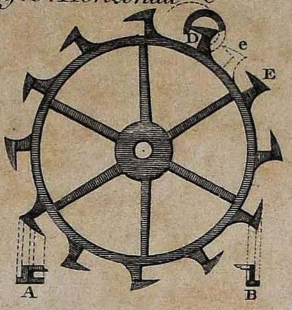


Fig. 6.
Free; for a Pendulum

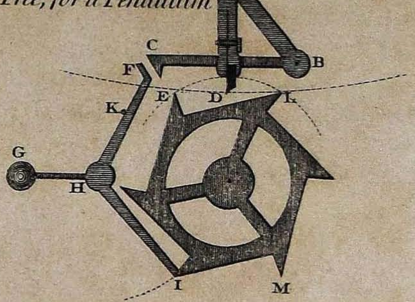


Fig. 7. Free or detached by Mudge

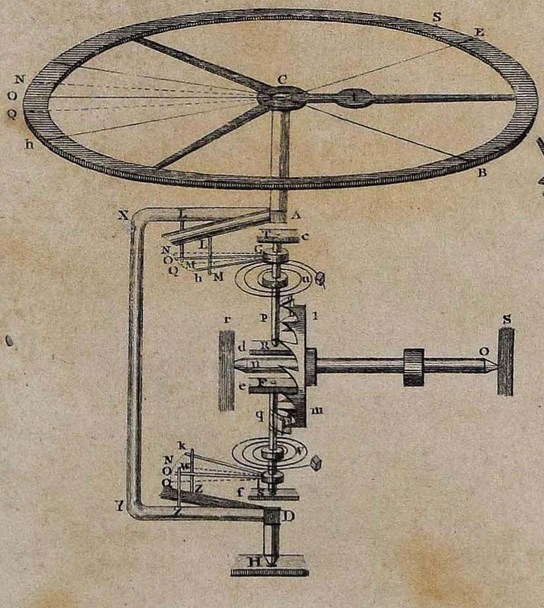
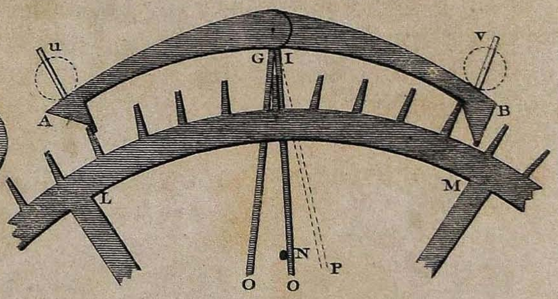


Fig. 8. Mudge's Esc. for a Pendulum



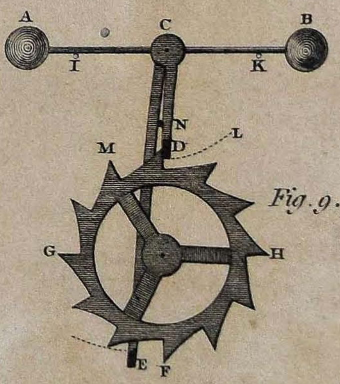


Fig. 9. W.N.

Barlow sculp.

Mr. Coulomb's method of exciting Magnetism.

Fig. 1.

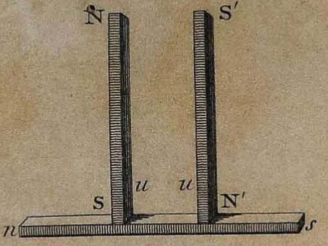


Fig. 2.

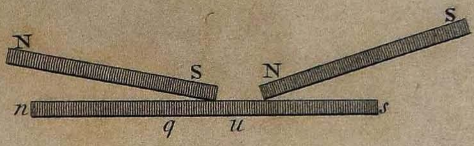


Fig. 3.

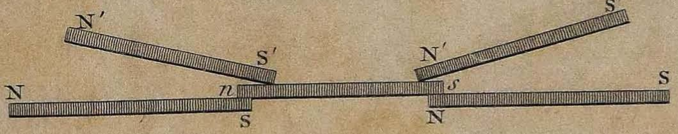
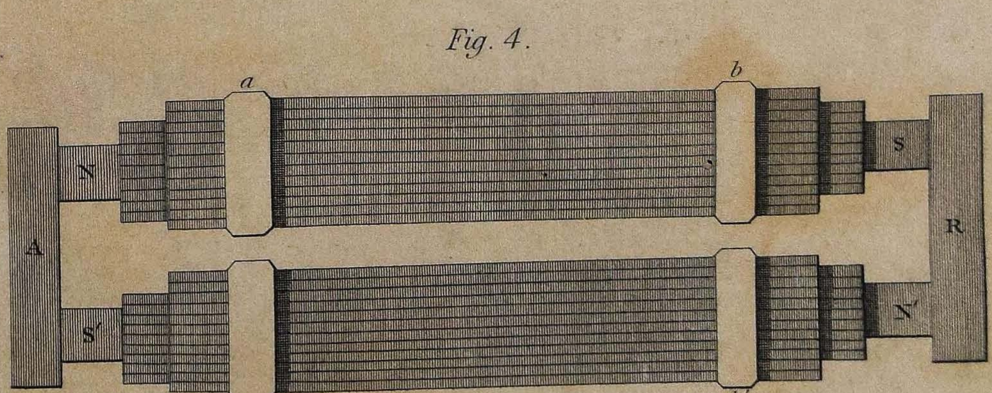


Fig. 4.



Barlow sculp.